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Vegetation structure and floristics at nest sites of grassland birds in north central North Dakota

Melvin P. Nenneman

The University of Montana

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Vegetation Structure and Floristics at Nest Sites of Grassland Birds in North Central North Dakota

By

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B. S., University of Wisconsin-Stevens Point, 1996

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Vegetation Structure and Floristics at Nest Sites of Grassland Birds in North Central North Dakota

Director: Dr. I. J. Ball

I studied nest-habitat selection of Savannah Sparrows (*Passerculus sandwichensis*), Clay-colored Sparrows (*Spizella pallida*), and Blue-winged Teals (*Anas discors*) in native mixed-grass prairie at J. Clark Salyer National Wildlife Refuge in north-central North Dakota. Vegetation structure and floristics were sampled at nests, within nest patches (habitat within 30 m of the nest), and within fields (random sampling within study units). I compared habitat features at nests, nest patches, and fields within different time periods following prescribed fire, and compared successful nests and the surrounding patch with failed nests and patches. Clay-colored Sparrow nesting habitat was defined by greater vegetation height and litter depth, and the availability of residual vegetation and shrubs. Savannah Sparrows used shorter vegetation and greater litter depth than that available within study units. Blue-winged Teals used vegetation with shorter structure and more residual vegetation. All three species selected nest sites with more heterogeneous plant communities. Within suitable grassland landscapes, my results indicate that habitat managers can manipulate vegetation at a nest site scale (< 5 m) to provide appropriate nesting structure for the species I studied. Differences between successful and failed nests were subtle, and suggested that habitat structure at the nest played only a small role in the outcome of a nesting attempt.

Acknowledgments

I acknowledge the guidance of my graduate committee throughout my graduate career. Dr. Joe Ball, Dr. Jeff Marks, Dr. Mark Lindberg, Dr. Dave Naugle, and Todd Grant provided advice to help me get through graduate school. Vanetta Burton and Jeanne Franz cheerfully answered my most mundane questions. Funding for my research and academic endeavors was provided by the U. S. Fish and Wildlife Service (Region 6 and J. Clark Salyer National Wildlife Refuge), the Joint Fire Science Program, Montana Cooperative Wildlife Research Unit, and The University of Montana Teaching Assistantships. Wes Newton and Deb Buhl (USGS, Northern Prairie Wildlife Research Center) provided statistical advice and patiently answered my questions. Many graduate students provided great friendship and insightful conversations, and I especially thank the "Duck Heads" (Steve Hoekman, Brian Logan, Mike Artmann, Alison Perkins, and Laura McHale) for sharing many meals and much conversation. Many thanks are owed to Beth Madden, Rachel Laubhan, Gordon Berkey, Johnida Martin, Silka Finkbeiner, Jenny Gault, Laurie Janzen, and Mitch Sternberg for their superb-nest finding skills. B. J. Schmidt, Elizabeth Johnson, and Erin Blenkhorn endured long hours of mosquitoes, heat, rain, and the tedium of recording vegetation data; their efforts are greatly appreciated. The staff at J. Clark Salyer National Wildlife Refuge provided invaluable support, great friendship, and wonderful cookouts. Many friends and family have provided valuable advice and support, and I especially thank Bob Murphy, Karen Smith, Beth Madden, and Todd Grant for being patient mentors, as well as great friends. Finally, thanks to my mother, who has always encouraged me to work hard and follow my dreams.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Grassland passerines are a topic of concern due to habitat loss and declining populations (Peterjohn and Sauer 1993, Knopf 1994). Analysis of Breeding Bird Survey (BBS) route trends for 25 species of grassland birds from 1966-1996 showed that this suite of birds has the smallest proportion of species showing positive trend estimates (Peterjohn and Sauer 1999). Additionally, 13 of the 25 species exhibited significantly declining population trends, versus only 3 with increasing trends. Destruction, fragmentation, and degradation of habitat have been cited as the common factors leading to declining bird populations (Askins 1993 , Igl and Johnson 1997, Peterjohn and Sauer 1999). European settlement during the mid-1800s resulted in the removal of native grazing animals, conversion of large areas of prairie to crop production, drainage of wetlands, and increases in woody vegetation (Knopf 1994, Samson and Knopf 1994, Flores 1996). Estimated percent losses in grassland habitat range from a low of 20% in Wyoming shortgrass prairie to more than 99% in most tallgrass prairie systems (Samson and Knopf 1994). Losses of grassland habitat in the prairie pothole region range from 50% in Montana to 89% in Iowa (Rude 1998). Despite recognition that native grasslands have undergone great losses in the last century, these grasslands continue to be converted to cropland (Kothmann 1995). Implementation of the Conservation Reserve Program and the North American Waterfowl Management Plan has returned considerable cropland to grassland, but much of this is planted to non-native grasses and forbs (Johnson and Schwartz 1993a, Prescott and Murphy 1999), which may not provide suitable habitat for some prairie avifauna (Wilson and Belcher 1989). Public grasslands have either been managed primarily as rangeland for cattle grazing in the case of national grasslands (Kothmann 1995) or to provide nesting cover for waterfowl and upland gamebirds on Waterfowl Production Areas and National Wildlife Refuges (Johnson 1997). Owing to fire suppression and the extirpation of bison (*Bison bison*), conditions on these remaining grasslands may differ substantially from those historically available. Periodic fire and intense grazing by bison combined to keep woody vegetation from invading grasslands (Campbell et al. 1994, Knopf and Sampson 1994). Varying grazing intensities by nomadic herds of bison created a heterogeneous landscape, whereas managed cattle grazing tends to create more homogeneous landscapes that can negatively affect endemic grassland assemblages (Knopf 1996a,b, Fuhlendorf and Engle 2001).

Little information is available on the nesting characteristics of most grassland birds, other than waterfowl and gallinaceous species (Kantrud and Higgins 1992). Although general habitat affinities are known for many grassland bird species, few studies provide quantified summaries of vegetative structure used by individual species. Most existing information on habitat selection by non-game species is limited to qualitative observations and quantitative descriptions based on habitat measurements conducted in areas where birds were observed (Renken and Dinsmore 1987, Johnson and Schwartz 1993b, Knopf 1994, Madden 1996, Davis et al. 1999). Several studies have shown that abundance and distribution of grassland birds are tied to vegetation structure (Rotenberry and Wiens 1980, Herkert 1994). However, few studies provide quantitative descriptions of vegetative structure and species composition based on measurements at nest sites (but see

Sutter 1997, Hoekman 1999, Logan 2001), and baseline information on nesting biology is lacking for most species (Kantrud and Higgins 1992, Davis and Sealy 1998).

Birds can select habitat at several spatial scales (Cody 1968, Wiens 1973, Johnson 1980). On the largest scale, many grassland breeding birds return to the Great Plains. Within this landscape, birds can select nesting habitat at a coarse level, such as a block of cropland or grassland. At a field level, some birds may prefer planted dense nesting cover, whereas others seek idle native pasture or heavily grazed native pasture. Patches of shrubs or of broad-leaved grasses may be selected within fields, and at the nest site, specific litter depth within a patch of Kentucky bluegrass (*Poa pratensis*) or vigorous new growth in native prairie may define habitat selection. Point-count data have been used to quantify habitat selection for breeding birds, but presence of a bird on a point-count plot does not prove that the species is nesting there, nor give any indication of breeding success (Van Horne 1989, Vickery et al. 1993).

The following chapters explore the role of plant structure and community composition at nest sites selected by three common grassland birds in North Dakota (Savannah Sparrow [*Passerculus sandwichensis*], Clay-colored Sparrow [*Spizella pallida*], and Blue-winged Teal [*Anas discors*]). Chapter Two examines habitat features of nest sites relative to the effects of prescribed burning and local habitat scale. In Chapter Three, habitat characteristics are compared between successful and failed nests of each species.

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CHAPTER 2

VEGETATION STRUCTURE AND FLORISTICS AT NEST SITES OF THREE GRASSLAND BIRDS IN NORTH-CENTRAL NORTH DAKOTA

Native grassland habitats underwent extensive changes following European settlement. Most prairie has been converted into agricultural fields, with losses of grassland habitat in the prairie pothole region ranging from 50% in Montana to 89% in Iowa (Rude 1998) and with losses in tallgrass prairie exceeding 99% (Samson and Knopf 1994). Conversion of grassland to cropland also altered the dynamic disturbance regime of periodic fire and intense bison grazing that minimized invasion of grasslands by woody vegetation (Campbell et al. 1994, Sampson and Knopf 1994). Loss, fragmentation, and degradation of remaining grasslands are common factors leading to declining populations of many grassland-nesting birds (Askins 1993 , Igl and Johnson 1997, Peterjohn and Sauer 1999). Population declines in many grassland species have prompted research focusing mostly on nest success, brood parasitism by Brown-headed Cowbirds (*Molothrus ater*), and edge and area effects (see Vickery and Herkert 2001). Despite increasing interest in the ecology of grassland birds, information on nesting ecology of many species in the northern Great Plains remains scarce (Kantrud and Higgins 1992). Many bird studies have used point counts to determine species abundance in grasslands and related observed abundances to habitat features measured within the study area (e.g. Owens and Myres 1973, Davis et al. 1999, Madden et al. 2000). Others have quantified habitat within territories mapped for individuals of a species (Rotenberry and Wiens 1980, Whitmore 1981, Zimmerman 1988, Herkert 1994). Few studies have used nest-sites to quantify habitat characteristics appropriate for nesting (but see Kantrud and Higgins 1992, Hoekman 1999, Logan 2001). Additionally, many nesting studies have occurred outside of the Great Plains in habitats such as hayfields and reclaimed mine sites that were not historically available for breeding (Whitmore 1981, Gavin and Bollinger 1988). Information on the life histories (e.g. nest-site selection, reproductive success, renesting, mortality) are important in providing a baseline for research on the effects of habitat management (Kantrud and Higgins 1992). Because habitat selection by a species may vary across its geographic range (Johnson and Igl 2001), habitat information from local areas may be necessary to adequately model habitat availability (Maurer 1986). I measured habitat features at nest sites of three common grassland birds (Savannah Sparrow [*Passerculus sandwichensis*], Clay-colored Sparrow [*Spizella pallida*], and Blue-winged Teal [*Anas discors*]) in north-central North Dakota to provide information on nesting habitat selection for these species. My objectives were to identify what habitat features are important in determining nest-site selection and at what local scale these features operated. I also investigated the effects of prescribed burning on nest-site selection. This information will assist grassland managers in providing nesting habitat for the species studied and will increase understanding of the costs and benefits of habitat manipulation on grasslands.

STUDY AREA

From 1999-2000, I measured habitat features of Clay-colored Sparrow, Savannah Sparrow, and Blue-winged Teal nests at J. Clark Salyer National Wildlife Refuge (hereafter Refuge) in North Dakota. The Refuge lies within the drift plain physiographic region, where the landscape is comprised of gently rolling hills and numerous wetlands (Bluemle 1991). Climate is subhumid continental, with average monthly temperatures ranging from -15° C in January to 20° C in July. Average annual precipitation from 1968-2001 was 44.60 cm, 54% of which fell from April to July (U.S. Fish Wildl. Serv. unpubl. data). The two years of my study are among the wettest recorded during this 34-year period. The wettest April to July (39.12 cm) occurred in 1999, and the highest annual precipitation (66.22 cm) was recorded in 2000.

The grassland selected for study was 445 ha of mixed-grass prairie adjacent to the Souris River. This native mixed-grass prairie, invaded by introduced Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*), was representative of many areas managed by the U. S. Fish and Wildlife Service in the region. This grassland was selected by U. S. Fish and Wildlife Service biologists (T. Grant and E. Madden) studying the effects of prescribed burning on the abundance, distribution, and reproductive success of grassland passerines. The study area was divided into seven study units of 40 to 97 ha, scheduled to be burned on a 3-4 year rotation (Table 1). Burns were conducted in late August, after the nesting season, so a year 1 unit was in its first growing season following fire treatment.

The vegetative community was comprised of native mixed and tall grasses,

Table 1. Study units at J. Clark Salyer National Wildlife Refuge and the number of growing seasons post-burn for each unit during the 1999-2000 breeding seasons.

	Number of growing seasons post-burn	
Burn Unit (ha)	1999	2000
A (69)	>3	1
C (43)	2	3
D (97)	>3	1
F (77)	1	2
G (49)	1	2
H (49)	2	3
I (40)	3	>3

primarily wheat grasses (*Agropyron* spp.), bluestems (*Andropogon* spp.), and needle-grasses (*Stipa* spp.), with many other grasses and forbs (mostly Asteraceae and Fabaceae; Great Plains Flora Association 1986). Kentucky bluegrass and smooth brome are prevalent across the area. Patches of low shrubs (snowberry [*Symphoriocarpos occidentalis*]) and noxious weeds (leafy spurge [*Euphorbia esula*]) are also common. Typical grassland-nesting birds in the area included Mallard (*Anas platyrhynchos*), Gadwall (*A. strepera*), Blue-winged Teal, Savannah Sparrow, Clay-colored Sparrow, and Chestnut-collared Longspur (*Calcarius ornatus*). Several other passerine species, three other waterfowl species, and two shorebird species also nested at lower densities on the study area (T. Grant, unpubl. data).

METHODS

Nests were located using 25-30 m rope drags with cans attached every 0.5 m.

Rope drags were pulled by two observers, and a third observer was often used to help spot flushing birds (Davis and Sealy 1998). Each study unit received equal search effort during the breeding season. Additional nests were located opportunistically when birds were flushed during field work or were observed carrying food or nesting materials. Nests were marked with two flags placed on opposite sides of the nest, approximately 3 to 5 m from the nest. Waterfowl nests were checked every 10-14 days. Passerine nests were checked every 3-4 days during egg laying, incubation, and early nestling periods, then daily as the young neared fledging.

To prevent excessive disturbance at active nests, I measured vegetation at nest sites after the nest had fledged young, or after the estimated date of fledging for failed nests. I measured three types of plots: nest plots, nest-patch plots, and field plots. Nest plots were centered on the nest of a Savannah Sparrow, Clay-colored Sparrow, or Blue-winged Teal. Nest-patch plots were located by pacing a random distance (between 5 and 30 m) and direction from the nest. Three nest-patch plots were measured at each nest to reduce the variability introduced by measuring atypical nest-patch plots (Sutter 1997). Nest plot and nest-patch plot measurements were done within seven days of nest termination. Fifteen field plots were selected within each study unit by locating randomly generated UTM coordinates with a GPS unit. All plots were 5-m radius circles centered on the nest, or on the center of the random plot. Vegetation measurements followed a modification of the BBIRD protocol (Martin et al. 1997; Table 2).

Within plots, a 7-mm diameter rod (Wiens 1969) marked in decimeter increments (centimeter increments for the first 2 dm) was passed vertically through the vegetation to

Table 2. Definitions of habitat features measured at nests, nest patch plots, and field plots at J. Clark Salyer NWR 1999-2000.

Habitat feature	Definition
Height density (dm)	Lowest segment on the Robel pole not completely obscured by vegetation, observed 4 m from the pole, with eye 1 m above ground.
CV Height density	Coefficient of variation of height density (measure of vertical heterogeneity)
Grass height (dm)	Highest dm in which a live grass hit was recorded on the Wiens rod
CV Grass height	Coefficient of variation of grass height
Residual hits	Total number of residual herbaceous hits recorded on the Wiens rod in the 1st dm
CV residual	Coefficient of variation of residual vegetation in the 1st dm
Litter depth (cm)	Height to which litter (residual herbaceous vegetation lying parallel to the ground) covered mineral soil.
Grass hits (%)	Percent of total Wiens rod hits comprised of live grasses
CV Grass hits	Coefficient of variation in grass hits
Forb hits (%)	Percent of total Wiens rod hits comprised of live forbs
CV Forb hits	Coefficient of variation in forb hits
Vegetation density	Total number of Wiens hits for the whole plot
Shrub distance (m)	Distance to nearest shrub averaged over 4 quadrats (index of shrub dispersion)
CV Shrub distance	Coefficient of variation in distance to nearest shrub
Heterogeneity index	Number of changes in vegetation community on vegetation transects; measure of spatial heterogeneity.

measure litter depth and vegetation hits in each decimeter increment. Measurements were taken at the plot center, or at the center of the nest bowl for nest plots, 1 cm outside the nest bowl, and at 1 m and 5 m from the plot center in the four cardinal directions (total of 13 measurements). A Robel pole (Robel et al. 1970) was used to measure vegetation height-density at the nest, 1 m, and 5 m from the center of the nest in each cardinal direction. For analysis, measures from the nest bowl and 1 cm outside the nest bowl were averaged to represent the nest bowl or plot center. Shrub dispersion was quantified using the point-centered quarter method (Elzinga et al.); distance to nearest woody stem $\geq$ 50 cm tall was measured in each quarter of the plot. Percent ground cover was visually estimated in each quadrant, using the Daubenmire scale (1 = 0-5%, 2 = 5-25%, 3 = 25-50%, 4 = 50-75%, 5 = 75-95%, and 6 = 95-100%). Plant species composition was measured using modified line transects (Grant et al. in review). At each plot center, four 5-m transects radiating from the center were established. The first transect direction was randomly chosen, and the remaining transects were placed at 90°, 180°, and 270° from the first. At every 0.5 m interval along each transect, the dominant plant group was recorded, resulting in 40 readings per plot. These plant groups were used to calculate frequency of occurrence for dominant vegetative cover (snowberry, smooth brome, Kentucky bluegrass, native grasses and forbs, exotic forbs, and wetland plants), and a heterogeneity index (number of changes in vegetation type across the four transects; Vickery et al. 1994).

I conducted statistical analyses using NCSS statistical software (Hintze 2001). To normalize data, I transformed percentage data using arcsine transformations, and other variables using log, square-root, cube-root, or reciprocal transformations. I used split-plot analysis of variance (ANOVA) to examine bird use of habitat. In the ANOVA model, unit by year combinations were used as blocks, and within these blocks nest plots, nest patch plots, and field plots were used as the plot level factor. Distance from plot center (measures of vegetation at the nest bowl or random plot center, 1 m and 5 m) was included as a subplot level factor. Blocks were nested within growing seasons post-burn (year 1, year 2, or year 3) to investigate the effects of burning on nest-site selection. This model allowed me to control for variation associated with year and study unit while determining the features affecting use of nest sites, the local spatial scale at which they operate, and the effects of burning on nest sites. I used Tukey-Kramer multiple comparison procedure to assess differences between means of significant interactions in each ANOVA. This test is conservative and is recommended when comparing all possible pairs (Hintze 2001). I considered $P < 0.05$ significant for post-hoc tests, the results of which are presented in Appendix A.

Because ground cover composition and frequency of plant groups from transects sum to one, I used a log-ratio transformation (Aebischer et al. 1993) and conducted MANOVA on the transformed data to determine if habitat compositions differed between nests, nest patches, and field plots.

RESULTS

Clay-colored Sparrow

Clay-colored Sparrows nested in vegetation that was taller and denser than available within nest patches and fields ($F_{4,66} = 13.38$, $P < 0.001$; Fig. 1). Additionally, vegetation height density was greatest within 1 m of the nest. Grass height at the nest bowl was greater in year 2 and year 3 units than at nest patch and field plot centers, and

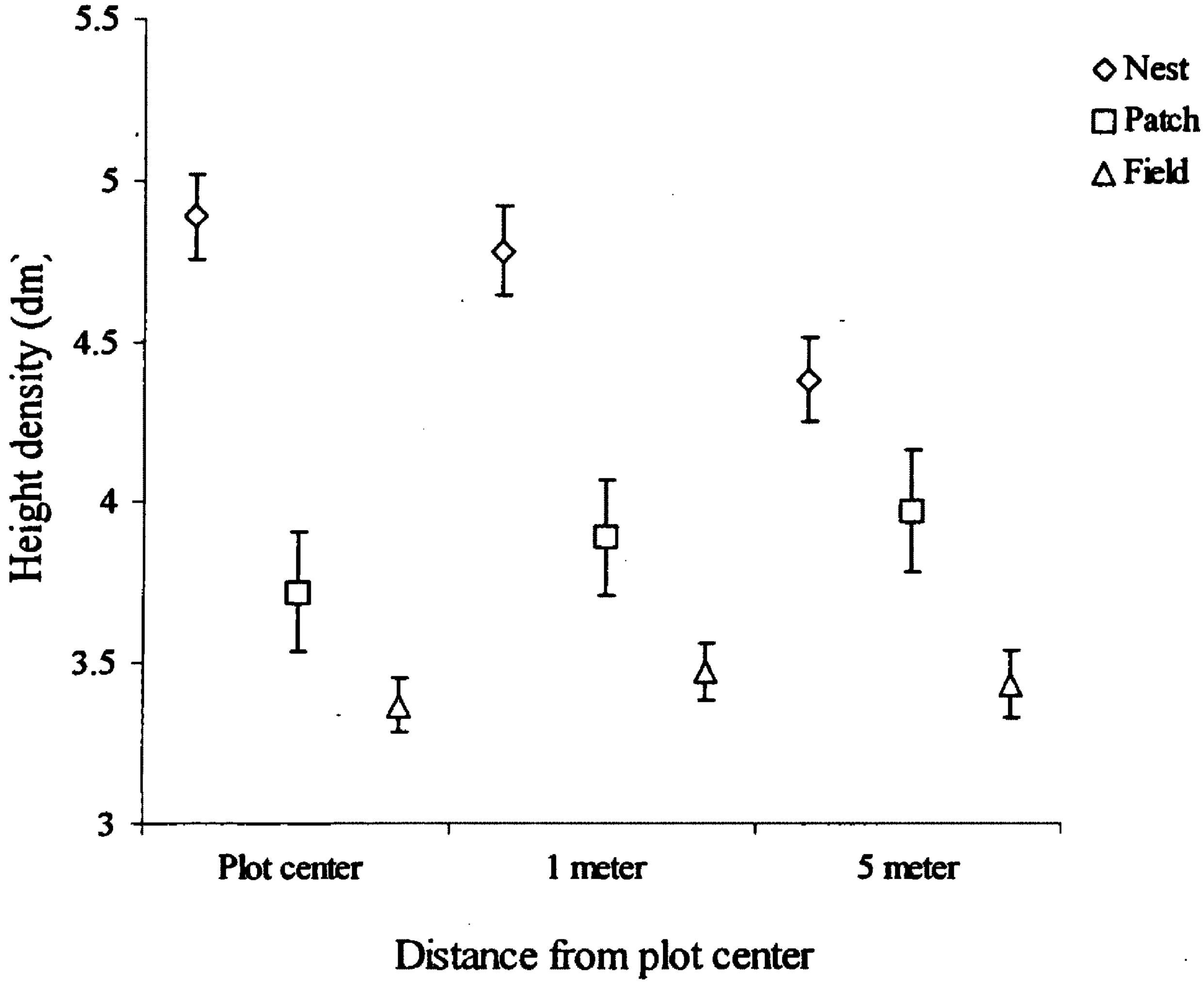

Figure 1. Mean (± SE) vegetation height density measured at Clay-colored Sparrow nest, patch, and field plots by distance from plot center at J. Clark Salyer NWR, 1999-2000. Sample size for nest, patch, and field plots are 89, 269, and 209.

height within nest plots in year 2 units was greater at the nest bowl than at 5 m ($F_{8,66}$ = 2.25, $P = 0.034$; Fig. 2). Litter depth at Clay-colored Sparrow nests was greater than at patch and field plot centers in year 1 units ($F_{8,66} = 2.86$, $P = 0.009$; Fig. 3), but litter depth did not differ at nests among years post-burn. Residual hits were correlated with litter depth (Spearman's rank $r_s = 0.883$, $P < 0.001$), and reflected the same pattern as litter depth, although the pattern was accentuated ($F_{8,66} = 8.55$, $P < 0.001$; Fig. 4). In year 1 units, nests had greater residual hits than patch and field plot centers, and within nest plots, nests had greater residual hits than at 1 and 5 m. Residual hits at nests in year 1 units were lower than nests in year 3 units at all distances measured. Vegetation density was greater at nest plots than at patch or field plots ($F_{2,22} = 30.57$, $P < 0.001$; Table 3). Percent grass was inversely correlated with dead hits (Spearman's rank $r_s = -0.615$, $P <$ 0.001), and differences reflected Clay-colored Sparrow preference for residual vegetation at the nest ($F_{8,66} = 6.23$, $P < 0.001$; Appendix A). Distance to nearest shrub differed among all plot types overall ($F_{2,22} = 315.83$, $P < 0.001$; Table 3), with nests being much closer to shrubs than patch or field plots. Nests and patches had greater vegetation heterogeneity than fields ($F_{2,22} = 20.82$, $P < 0.001$; Table 3). Ground cover compositions (Wilk's lambda = 0.112, $F_{8,60} = 14.95$, $P < 0.001$) and plant group frequencies (Wilk's lambda = 0.091, $F_{10,58} = 13.39$, $P < 0.001$) differed among plot types, with nests having greater shrub cover and less grass cover than patches and field plots (Fig. 5). Smooth brome was the least preferred grass understory (Fig. 5).

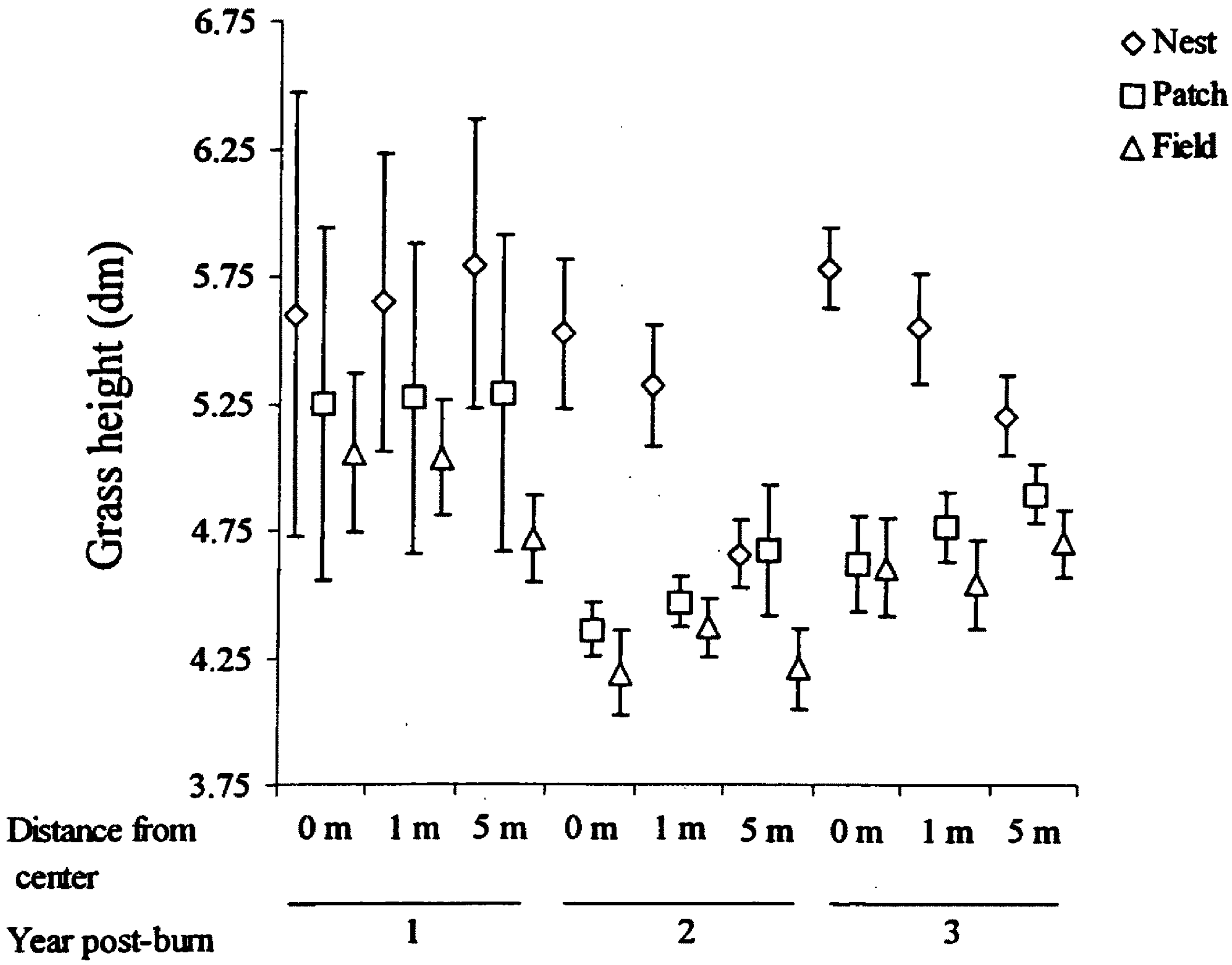

Figure 2. Mean (± SE) grass height by year post-burn and distance from plot center measured at Clay-colored Sparrow nest, patch, and field plots at J. Clark Salyer NWR in 1999-2000. Sample size by year post-burn for nest plots are 25, 32, 32; for patch plots are 75, 96, 96; and for field plots are 60, 60, 89.

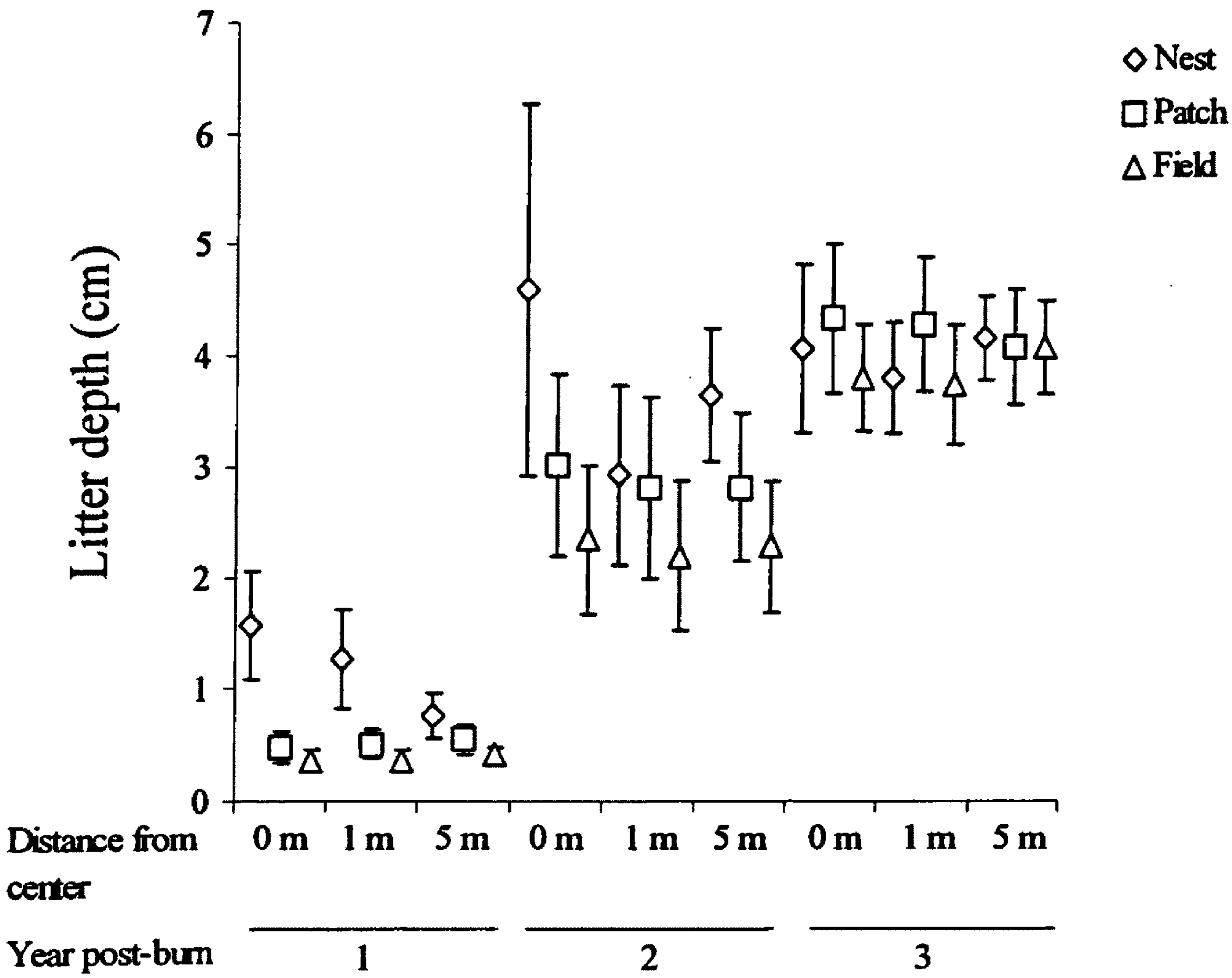

Figure 3. Mean (+ SE) litter depth (cm) at Clay-colored Sparrow nests, patches and field plots at J. Clark Salyer NWR in 1999-2000. Sample sizes by year post-burn for nests are 25, 32, 32; for patches are 75, 96, 96; and for fields are 60, 60, 89.

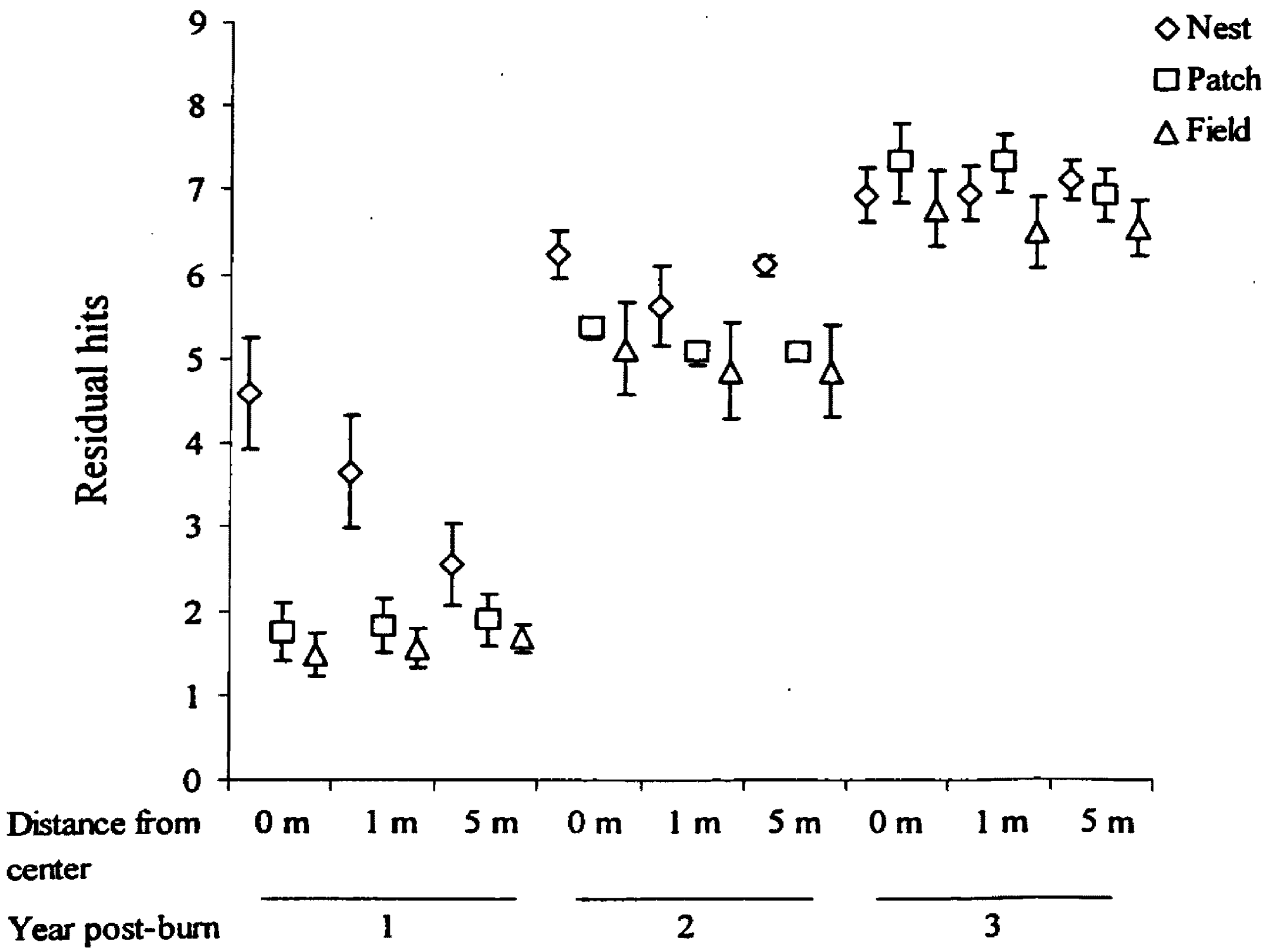

Figure 4. Mean (± SE) residual herbaceous hits in the 1st dm at Clay-colored Sparrow nests, patches, and field plots at J. Clark Salyer NWR in 1999-2000. Sample sizes by year post-burn for nests are 25, 32, 32; for patches are 75, 96, 96; for fields are 60, 60, 89.

Table 3. Mean (SD) of habitat features of Clay-colored Sparrow nests, nest patches, and field plots measured at J. Clark Salyer NWR, 1999-2000. Within rows, columns with different letters are significantly different ($q = 3.55$, df = 22, $P \leq 0.05$). Bold type indicates a significant interaction, and post-hoc results are presented in Appendix A.

	Untransformed means (SD) by plot type		
Habitat Feature	Nest Plot (n = 89)	Nest Patch (n = 267)	Field Plots (n = 209)
Height density (dm)	4.69 (0.54)	3.86 (0.69)	3.43 (0.35)
CV Height density	0.2049 (0.0833)	0.2077 (0.0582)	0.2157 (0.0631)
Grass height (dm)	5.46 (0.80)	4.83 (0.73)	4.61 (0.46)
CV Grass height	0.2460 (0.1525)	0.2653 (0.0809)	0.2660 (0.0625)
Litter (cm)	3.14 (1.32)	2.79 (1.95)	2.43 (1.76)
Residual hits	5.76 (1.72)	5.11 (2.37)	4.72 (2.30)
CV Dead hits	0.3521 (0.1392)	0.4469 (0.2815)	0.4409 (0.2904)
Vegetation density	265.41 (37.11) A	215.39 (37.91) B	206.24 (34.27) B
Grass hits (% of total)	45.81 (12.24)	55.53 (13.65)	61.79 (12.49)
CV Grass Hits	0.3527 (0.1571)	0.2944 (0.1452)	0.2678 (0.1703)
Forb hits (% of total)	3.03 (2.41)	5.01 (3.23)	4.19 (2.98)
CV % Forb	0.9304 (0.5057)	0.9681 (0.2773)	0.9408 (0.2377)
Distance to shrub (m)	1.09 (1.40) A	12.88 (4.39) B	26.68 (4.11) C
CV Dist. to shrub	0.7879 (0.1467) A	0.6712 (.1100) B	0.6190 (0.0671) B
Heterogeneity index	17.12 (5.64) A	16.94 (5.72) A	10.71 (1.79) B

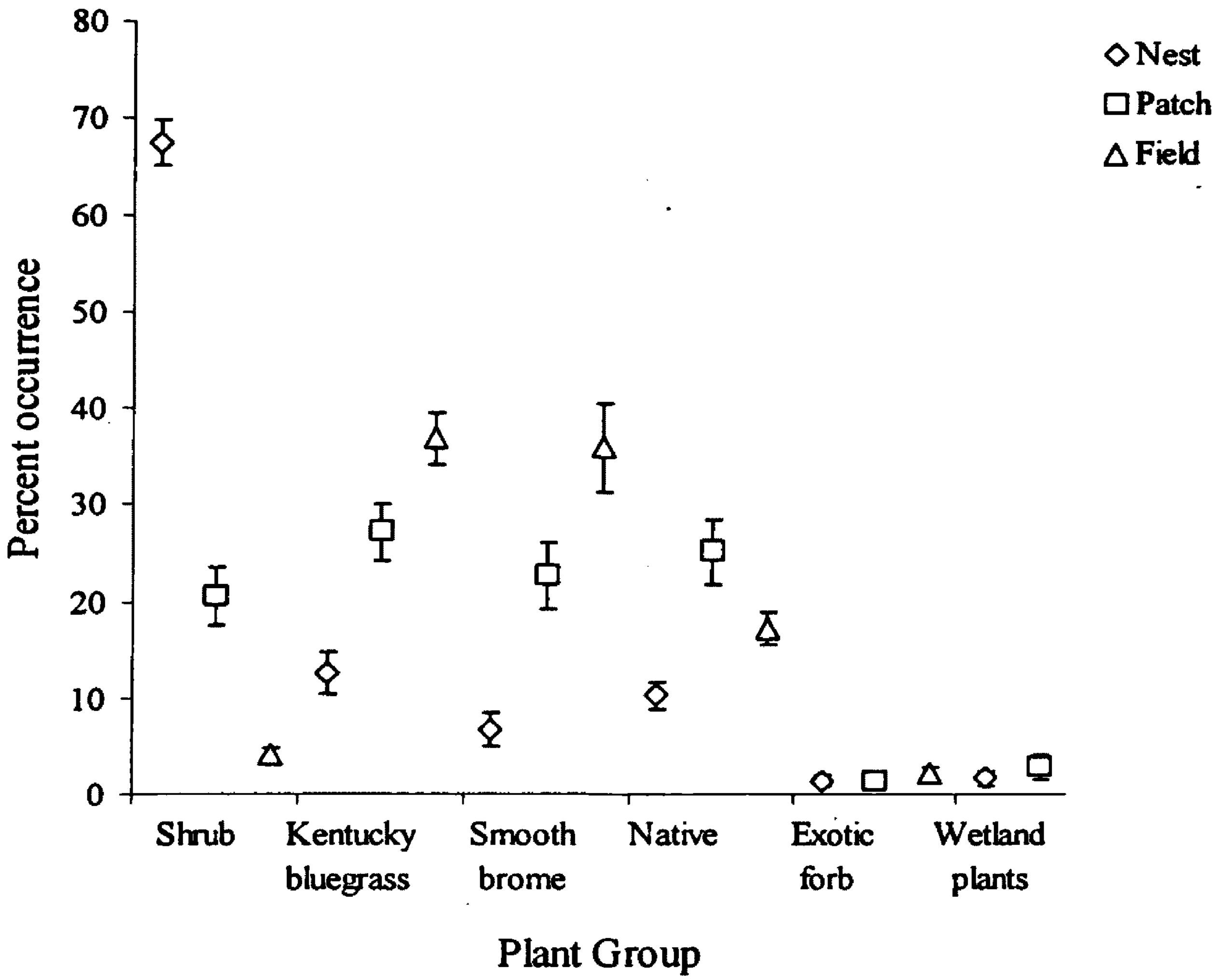

Figure 5. Mean (± SE) percent occurrence by plant group at Clay-colored Sparrow nests, patches, and field plots at J. Clark Salyer NWR in 1999-2000. Sample sizes for nests, patches and field plots are 89, 267, and 209.

Savannah Sparrow

Savannah Sparrows nested in vegetation that had lower height density than available within fields at the nest/center and 1 m ($F_{4,66}$ = 3.15, P = 0.020; Fig 6). Similarly, grass height in nest plots was lower than in patch or in field plots ($F_{2,22}$ = 11.93, P <0.001; Table 4). Vegetation density differed between nest plots and patch plots ($F_{2,22}$ = 13.54, P <0.001), but not between nest plots and field plots (Table 4). Litter depth varied across years post-burn, type, and distance from the nest ($F_{8,66}$ = 9.11, P < 0.001). Litter depth at the nest bowl was similar across years post-burn (Fig. 7). Nest bowls in year 1 units had greater litter than nest-patch and field-plot centers, and within the nest plot, nest bowls had greater litter depth than at 1 m and 5 m (Fig. 7). Residual hits were correlated with litter depth (Spearman's rank r_s = 0.912, P < 0.001) and did not differ at nests across years post-burn ($F_{8,66}$ = 11.53, P < 0.001; Fig. 8). Also, in year 1 units, nests had more residual hits than nest patch and field plot centers, and within the nest plot, nests had greater residual hits than at 1 and 5 m. Variation in residual hits was similar for nest bowls across years post-burn, but variation was significantly less for nest bowls in year 1 units than at patch- and field-plot centers ($F_{8,66}$ = 5.06, P < 0.001; Fig 9). Grass hits in year 1 were lower at the nest than at patch or field centers ($F_{8,66}$ = 2.70, P = 0.012; Fig 10), and by year 3 both nest and patch plots had significantly lower percentages of grass hits than field plots. Vegetation heterogeneity at nest and patch plots was greater than at field plots ($F_{2,22}$ = 16.05, P < 0.001, q = 3.55, df = 22, $P \leq$ 0.05; Table 4). Plant group frequency differed among types (Wilk's lambda = 0.291, $F_{10,58}$ = 4.95, P < 0.001), with nests and patches having less Kentucky bluegrass and more native and shrub

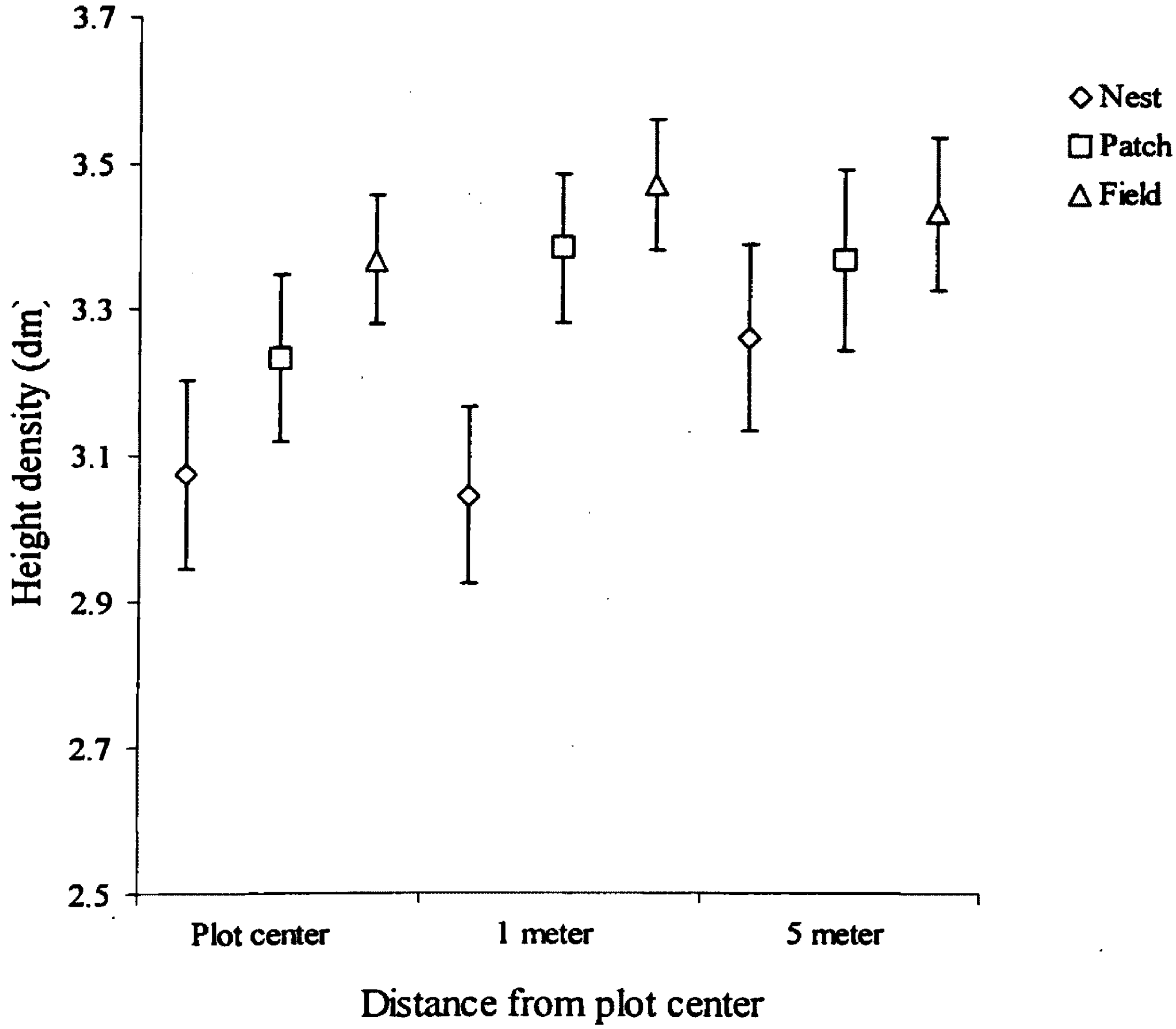

Figure 6. Mean (± SE) vegetation height density (dm) at Savannah Sparrow nests, patches, and field plots at J. Clark Salyer NWR in 1999-2000. Sample sizes for nests are 94, for patches are 282, and for fields are 209.

Table 4. Mean (SD) of habitat features measured at Savannah Sparrow nests, nest patches, and field plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences ($q = 3.55$, df = 22, $P \leq 0.05$). Bold type indicates a significant interaction, and post-hoc results are presented in Appendix A.

	Untransformed means (SD) by plot type		
Habitat Feature	Nest Plots (n = 94)	Nest Patches (n =282)	Field Plots (n =209)
Height density (dm)	3.13 (0.47)	3.33 (0.42)	3.43 (0.35)
CV Height density	0.22 (0.06)	0.22 (0.06)	0.22 (0.06)
Grass height (dm)	4.16 (0.45) A	4.42 (0.48) B	4.61 (0.46) B
CV Grass height	0.30 (0.08)	0.29 (0.06)	0.27 (0.06)
Vegetation density	197.50 (27.38) A	179.67 (37.15) B	206.24 (34.27) A
Litter (cm)	2.67 (1.60)	2.31 (1.61)	2.43 (1.76)
Residual hits	5.53 (1.96)	4.71 (2.16)	4.72 (2.30)
CV residual	0.43 (0.28)	0.52 (0.30)	0.44 (0.29)
Grass hits (% of total)	50.67 (12.66)	55.81 (14.16)	61.79 (12.49)
CV Grass hits	0.3225 (0.1381)	0.3197 (0.1488)	0.2678 (0.1703)
Forb hits (% of total)	4.81 (2.85)	4.80 (2.24)	4.19 (2.98)
CV % Forb	0.9276 (0.3231)	0.9756 (0.2203)	0.9408 (0.2377)
Distance to shrub (m)	26.17 (7.35)	25.93 (7.89)	26.68 (4.11)
CV Dist. to shrub	0.59 (0.15)	0.60 (0.09)	0.62 (0.07)
Heterogeneity index	17.09 (5.42) A	15.25 (5.32) A	10.71 (1.79) B

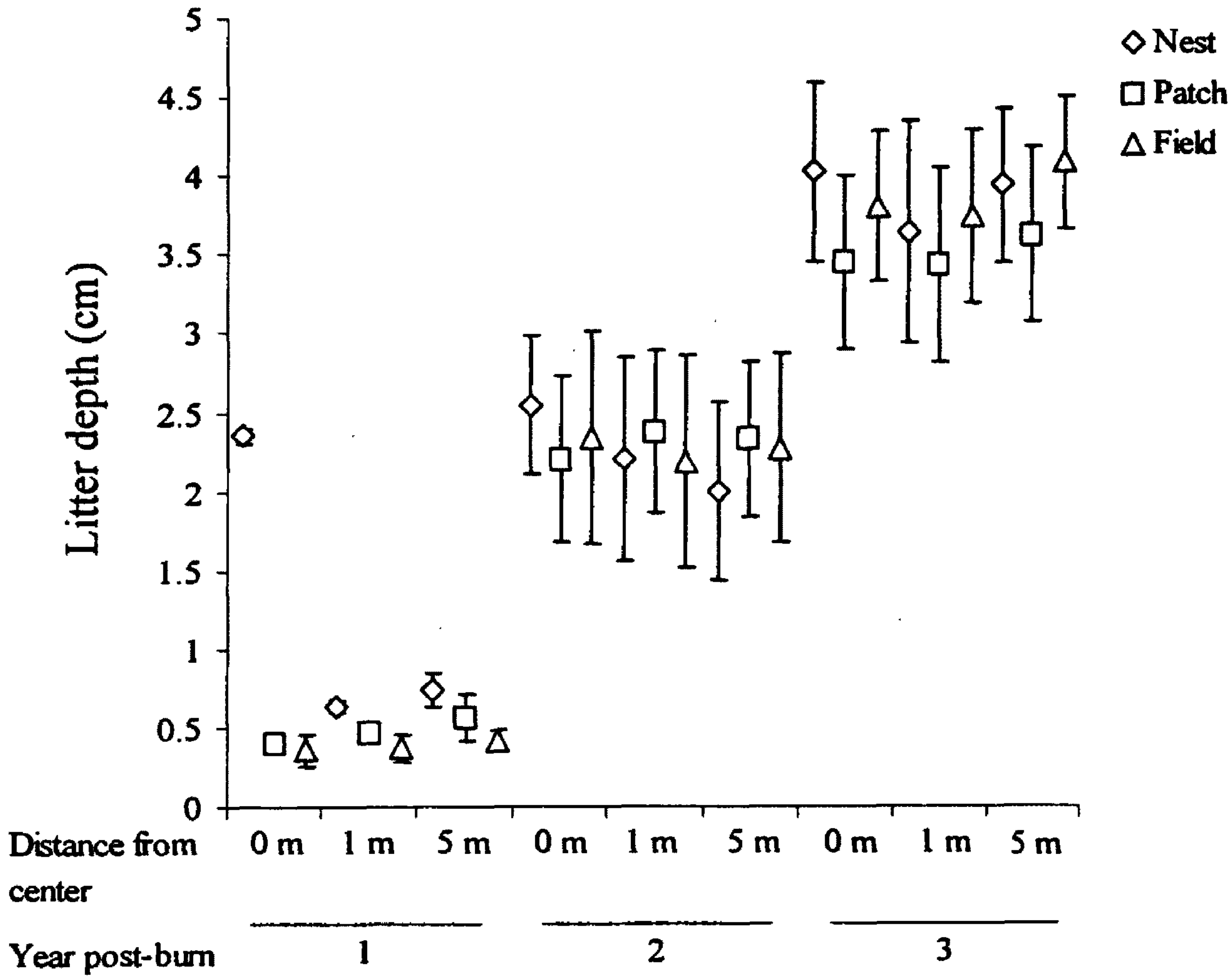

Figure 7. Mean (± SE) litter depth (cm) at Savannah Sparrow nests, patches, and field plots at J. Clark Salyer NWR in 1999-2000. Sample sizes by year post-burn for nests are 30, 32, 32; for patches are 90, 96, 96; and for fields are 60, 60, 89.

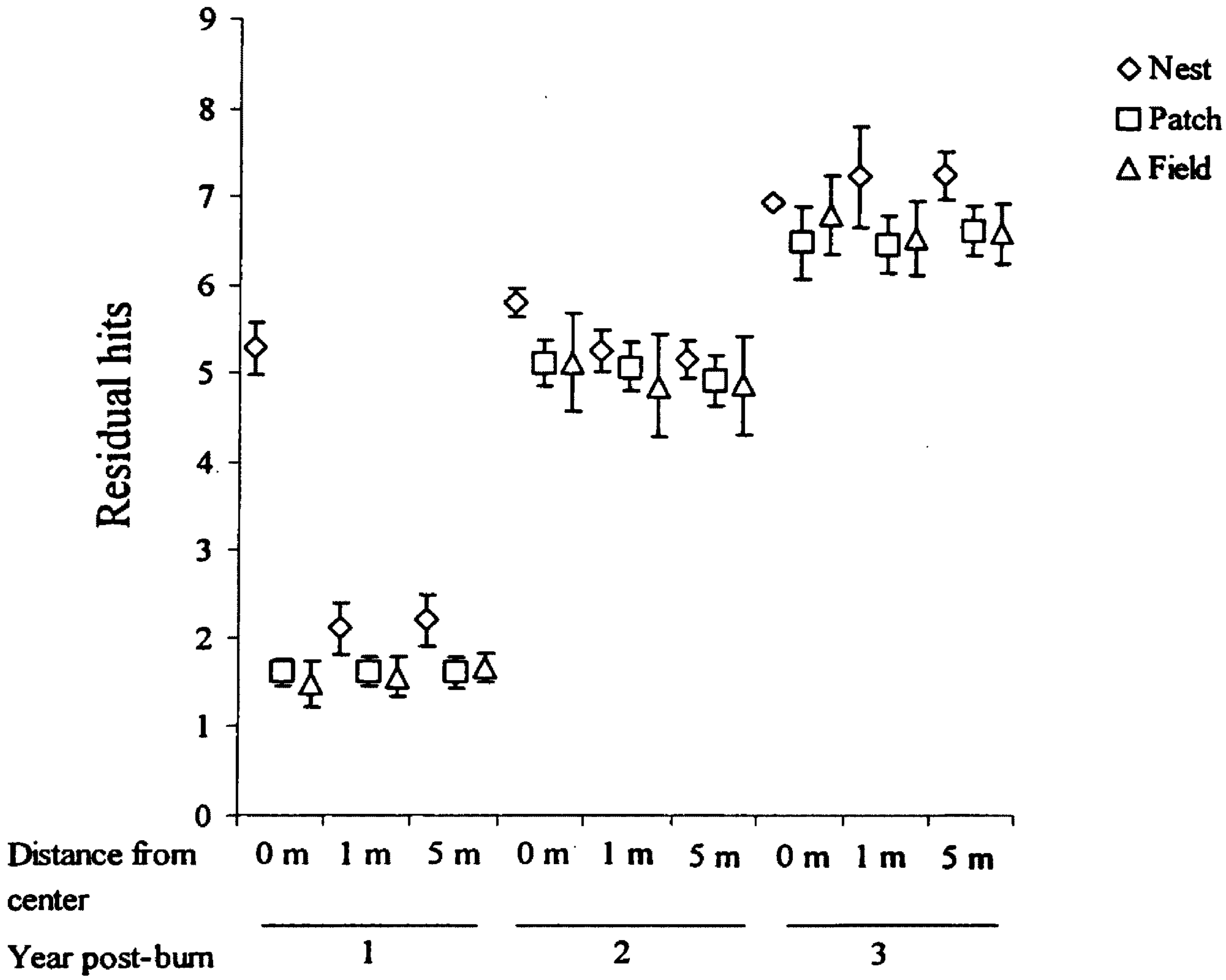

Figure 8. Mean (± SE) residual hits at Savannah Sparrow nests, patches, and field plots at J. Clark Salyer NWR in 1999-2000. Sample sizes by year post-burn for nests are 30, 32, 32; for patches are 90, 96, 96; and for fields are 60, 60, 89.

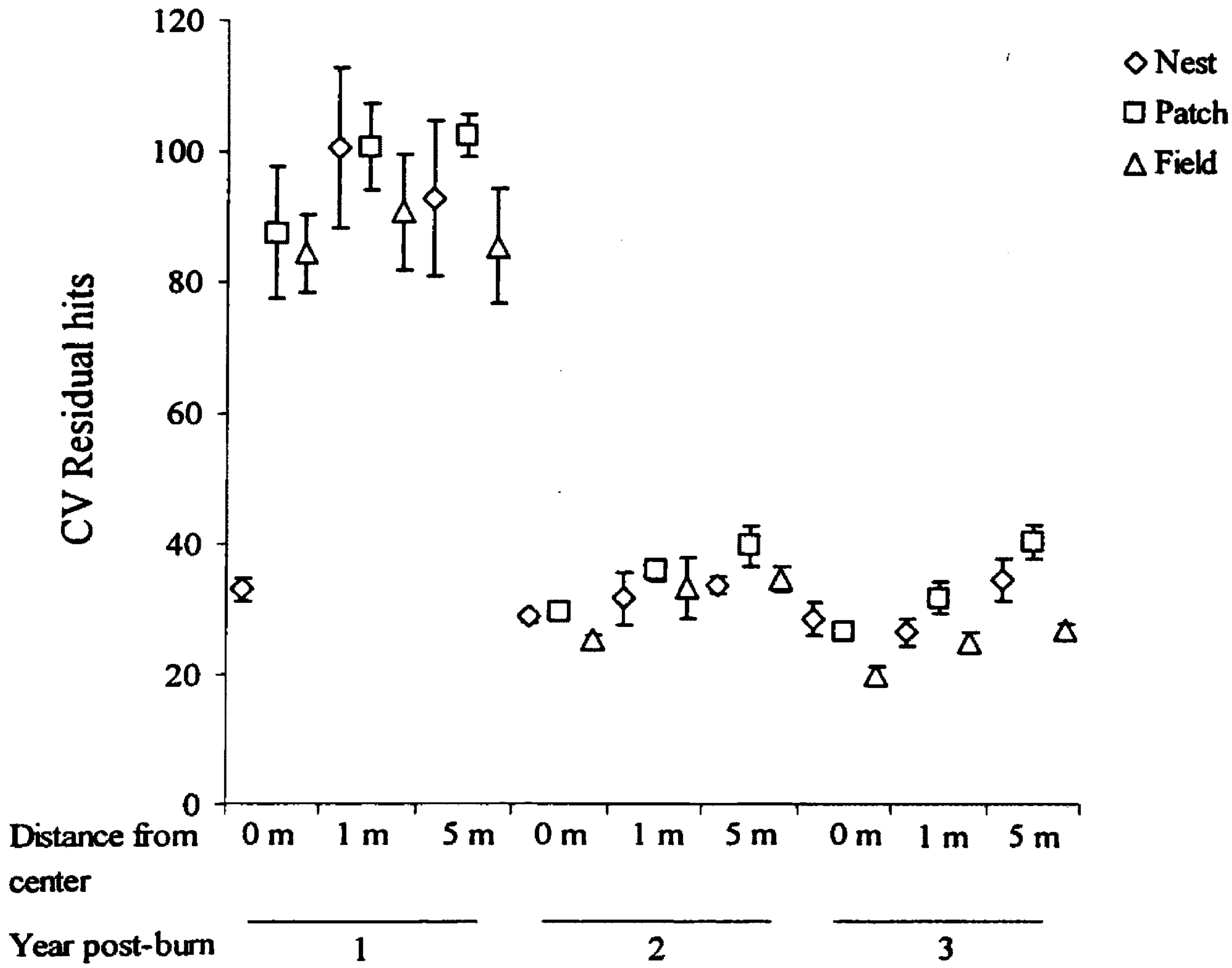

Figure 9. Mean (+ SE) coefficient of variation in residual vegetation hits at Savannah Sparrow nest, patch, and field plots at J. Clark Salyer NWR in 1999-2000. Sample sizes by year post-burn for nests are 30, 32, 32; for patches are 90, 96, 96; and for fields are 60. 60. 89.

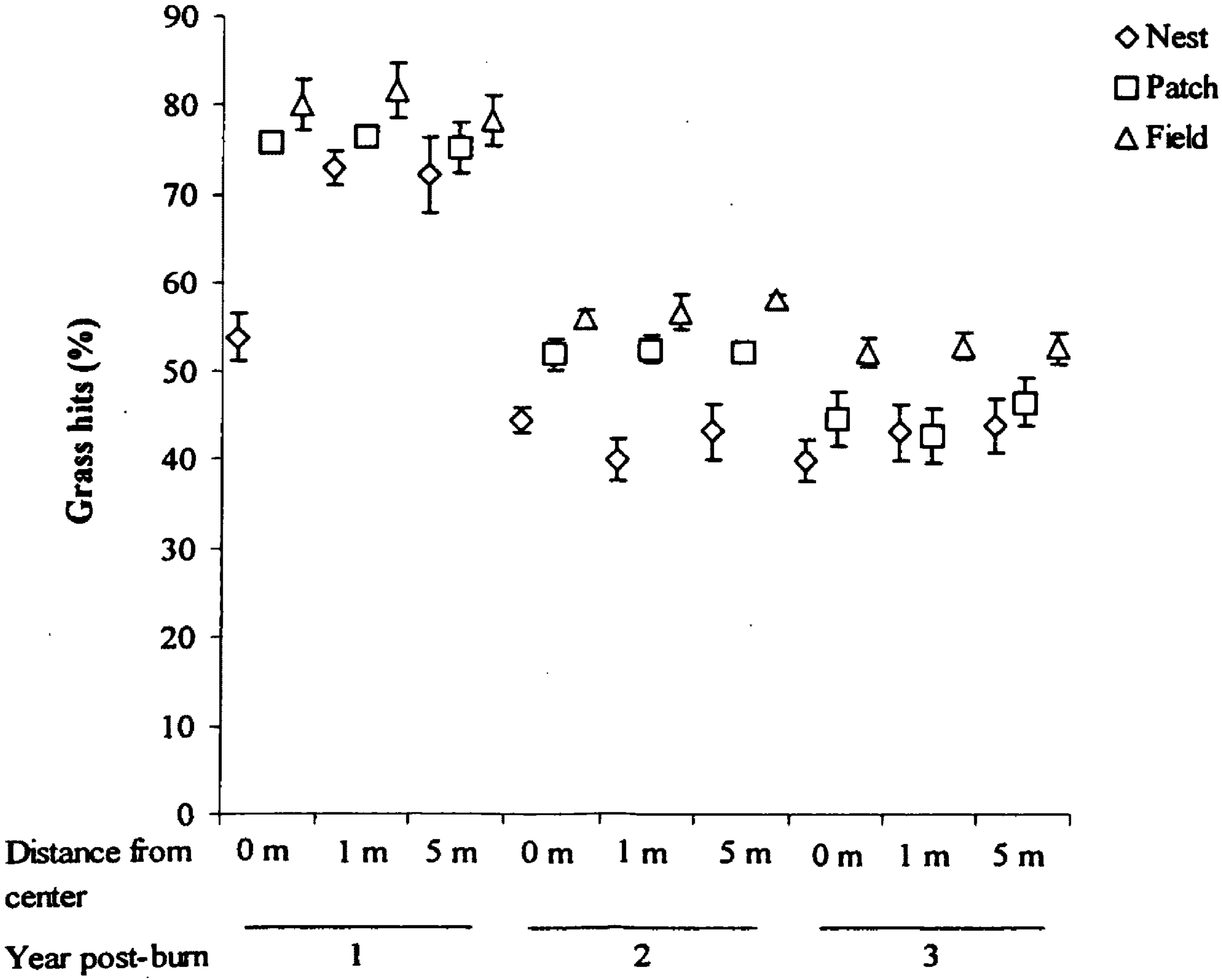

Figure 10. Mean (± SE) percent grass hits at Savannah Sparrow nests, patches, and fields at J. Clark Salyer NWR in 1999-2000. Sample sizes by year post-burn for nests are 30, 32, 32; for patches are 90, 96, 96; and for fields are 60, 60, 89.

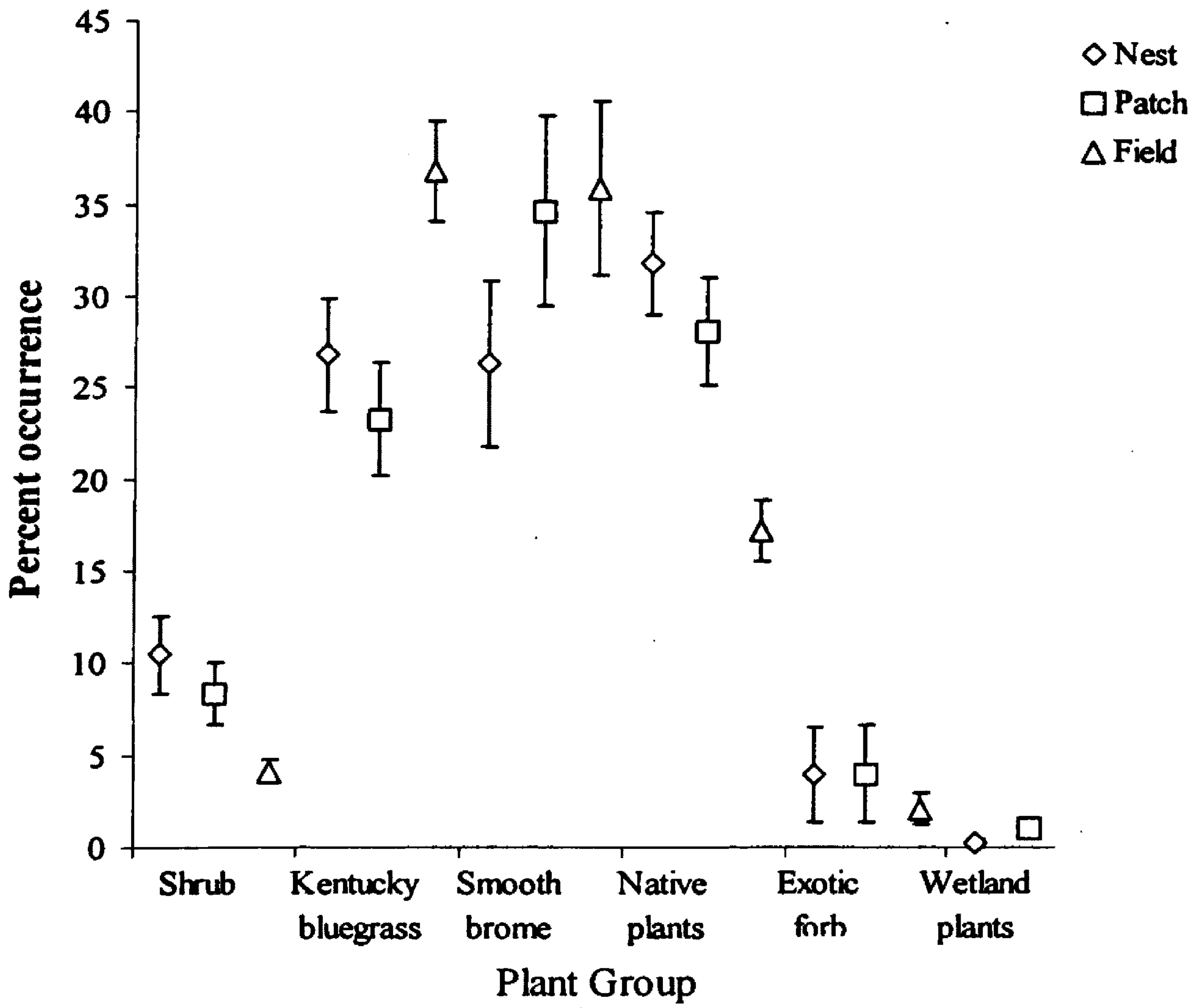

Figure 11. Mean (± SE) percent occurrence by plant group at Savannah Sparrow nest, patch, and field plots at J. Clark Salyer NWR in 1999-2000. Sample size for nests is 94, for patches is 282, and for fields is 209.

cover than field plots (Fig. 11). Nest plots also had less smooth brome than field plots.

Blue-winged Teal

Blue-winged Teal nest plots did not differ from patch or field plots (Table 5), although several interactions were significant. Litter depth varied by year post-burn and by plot type ($F_{4,12}$ = 4.30, P = 0.022; Fig 12), but post hoc tests revealed that year post-burn drove this difference. Residual hits also differed primarily by year post-burn, but in first year post-burn units, nest plots and patch plots had more residual hits than field plots ($F_{4,12}$ = 82.06, $P \leq$ 0.001; Fig. 13). Within nest plots, the nest bowl had more grass hits than at 5 m. Nest plots and patch plots had less grass hits than field plots ($F_{4,46}$ = 4.27, P = 0.005; Fig. 14). Distance to the nearest shrub varied by year post-burn and type ($F_{4,12}$ = 3.54, P = 0.040), but post-hoc tests did not detect differences between means. However, it appears that nests and nest patches in year 1 were closer to shrubs than field plots (Fig. 15). Heterogeneity at nest plots and patch plots was greater than available in field plots for all years post-burn, and was greater at nests in year 1 and year 2 than in year 3 units ($F_{4,12}$ = 21.83, P < 0.001; Fig 16). Plant group frequency differed among nests, nest patches, and field plots (Wilk's lambda = 0.172, $F_{10,38}$ = 5.37, P < 0.001). Nests and nest patches had more native grass and shrub cover and less Kentucky bluegrass cover than field plots (Fig. 17).

Table 5. Mean (SD) of habitat features measured at Blue-winged Teal nests, paired nest random plots, and field random plots at J. Clark Salyer NWR, 1999-2000. Bold type indicates a significant interaction, and post-hoc results are presented in Appendix A.

	Untransformed means (SD) by plot type		
Habitat Feature	Nest Plots (n = 56)	Nest Patches (n = 168)	Field Plots (n = 209)
Height density (dm)	3.23 (0.86)	3.44 (0.86)	3.43 (0.35)
CV Height density	0.2408 (0.0747)	0.2338 (0.0781)	0.2157 (0.0631)
Grass height (dm)	4.26 (0.64)	4.43 (0.72)	4.61 (0.46)
CV Grass height	0.3214 (0.1321)	0.2738 (0.0704)	0.2660 (0.0625)
Litter (cm)	1.97 (1.43)	1.94 (1.69)	2.43 (1.76)
Residual hits	5.08 (1.74)	5.04 (2.03)	4.72 (2.30)
CV Dead hits	0.4880 (0.1370)	0.4363 (0.1363)	0.4409 (0.2904)
Vegetation density	198.52 (31.34)	196.50 (42.04)	206.24 (34.27)
Grass hits (% of total)	49.94 (10.92)	48.84 (9.94)	61.79 (12.49)
CV Grass hits	0.3646 (0.1384)	0.3347 (0.0857)	0.2678 (0.1703)
Forb hits (% of total)	3.57 (2.57)	4.53 (2.81)	4.19 (2.98)
CV % Forb hits	0.9375 (0.5038)	0.8801 (0.3382)	0.9408 (0.2377)
Distance to shrub (m)	23.59 (11.54)	23.25 (11.61)	26.68 (4.11)
CV Dist. to shrub	0.6780 (0.1369)	0.6479 (0.0986)	0.6190 (0.0671)
Heterogeneity index	18.06 (6.55)	16.37 (7.48)	10.71 (1.79)

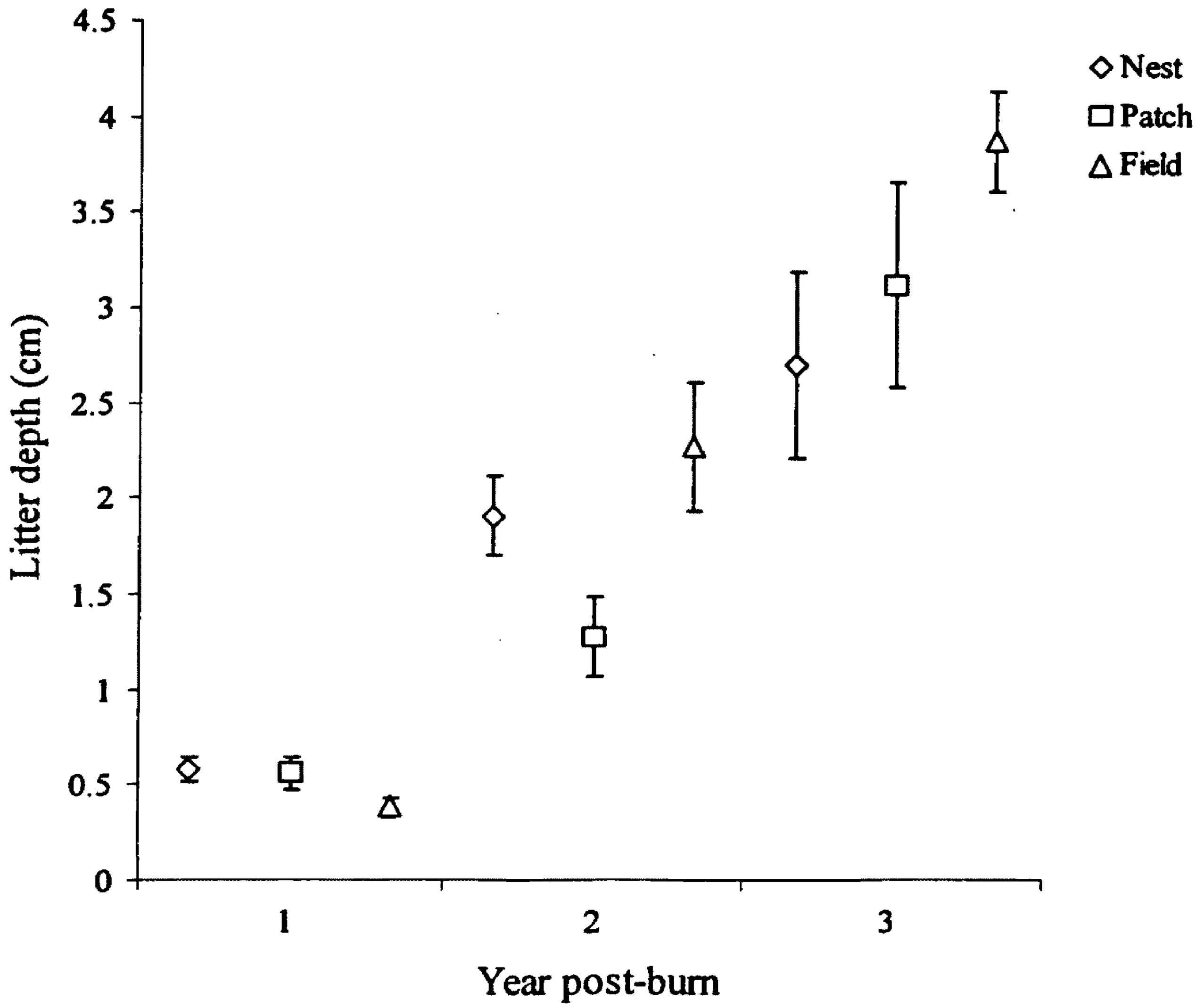

Figure 12. Mean (± SE) litter depth (cm) at Blue-winged Teal nest, patch, and field plots at J. Clark Salyer NWR in 1999-2000. Sample sizes for nests by year post-burn are 16, 20, 20; for patches are 48, 60, 60; and for fields are 60, 60, 89.

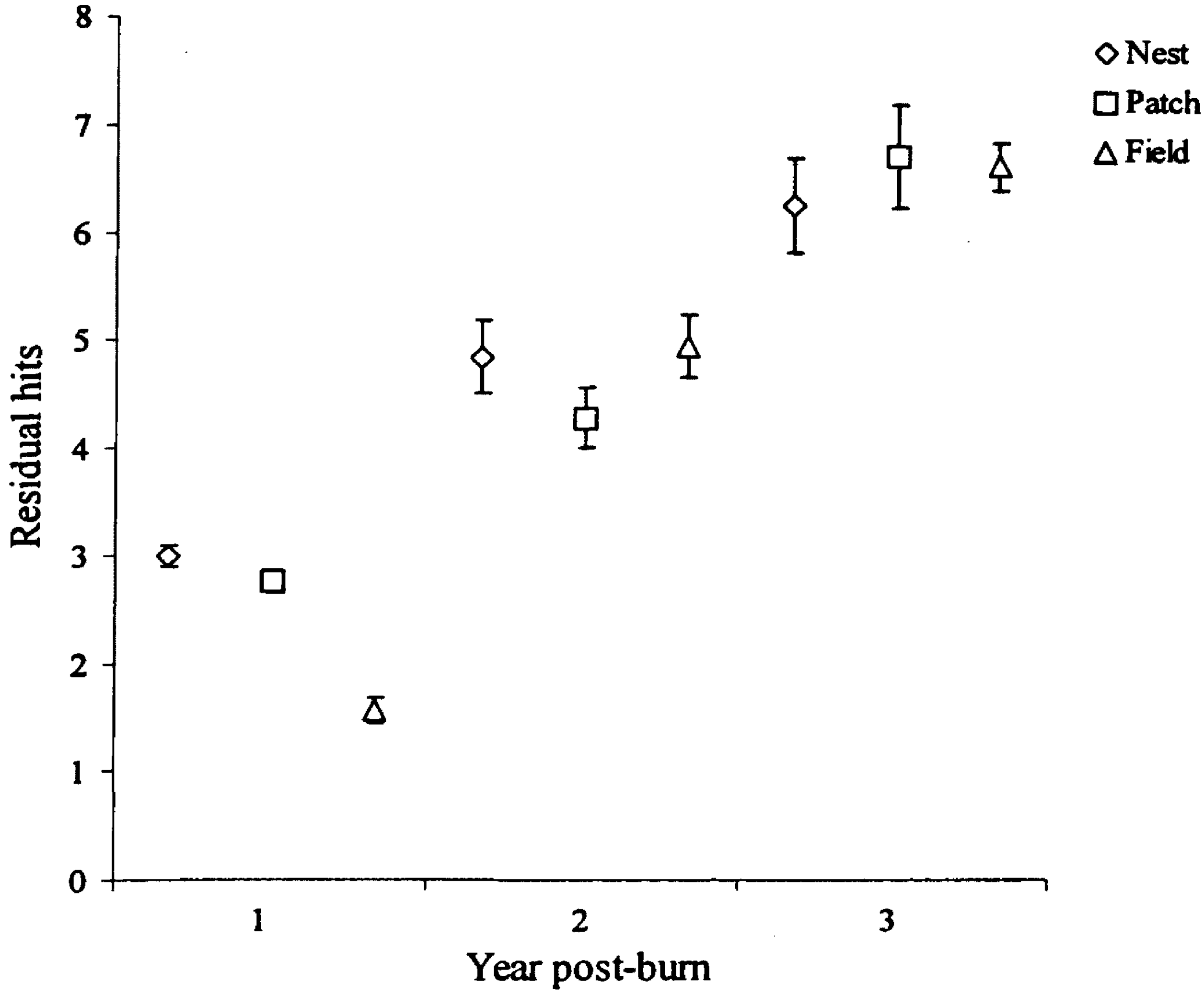

Figure 13. Mean (± SE) residual herbaceous hits in 1st dm at Blue-winged Teal nest, patch, and field plots at J. Clark Salyer NWR in 1999-2000. Sample sizes for nest plots by year post-burn are 16, 20, 20; for patch plots are 48, 60, 60; and for field plots are 60, 60, 89.

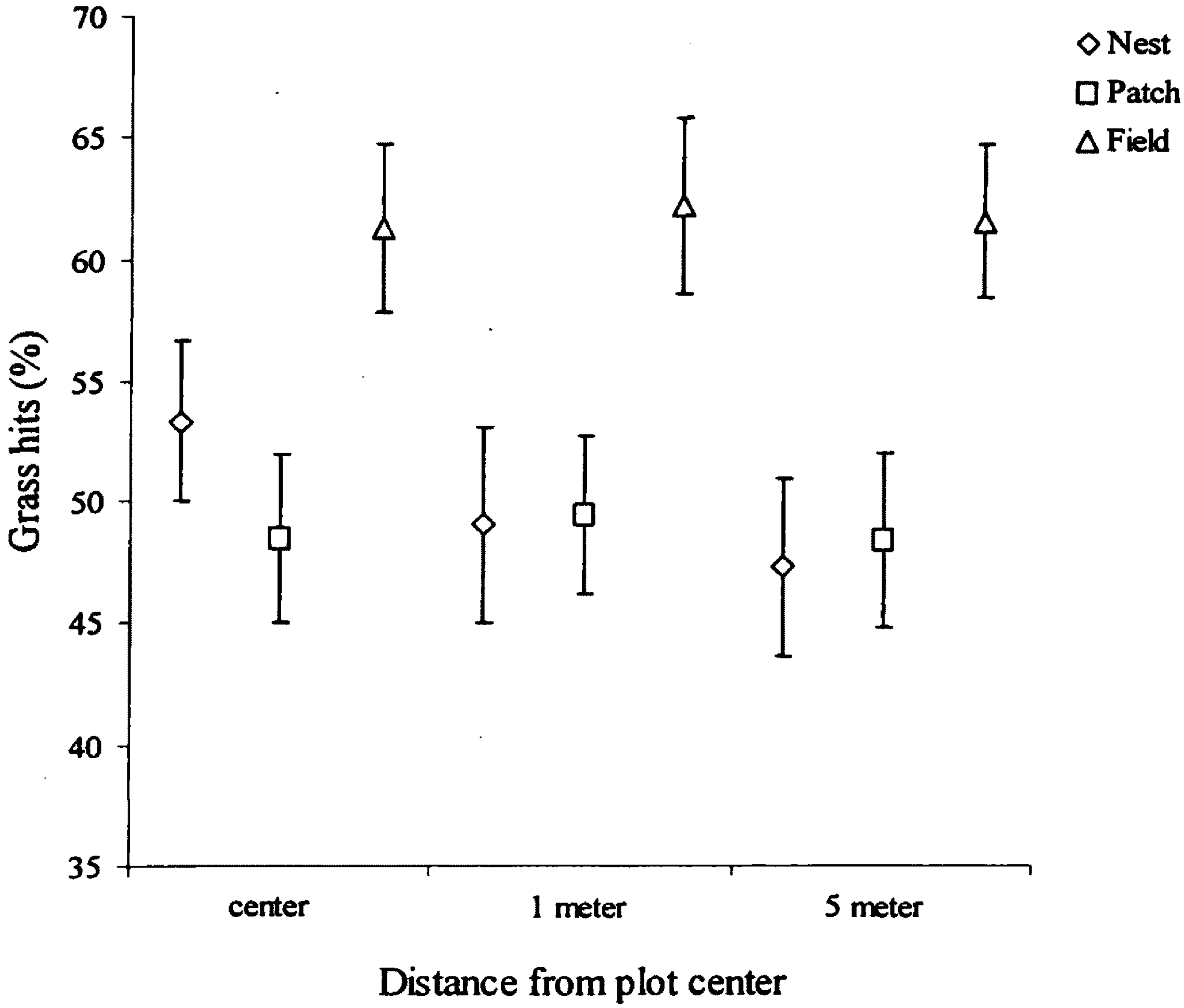

Figure 14. Mean (± SE) percent live grass hits at Blue-winged Teal nest, patch, and field plots at J. Clark Salyer NWR in 1999-2000. Sample size for nest plots are 56, for patch plots are 168, and for field plots are 209.

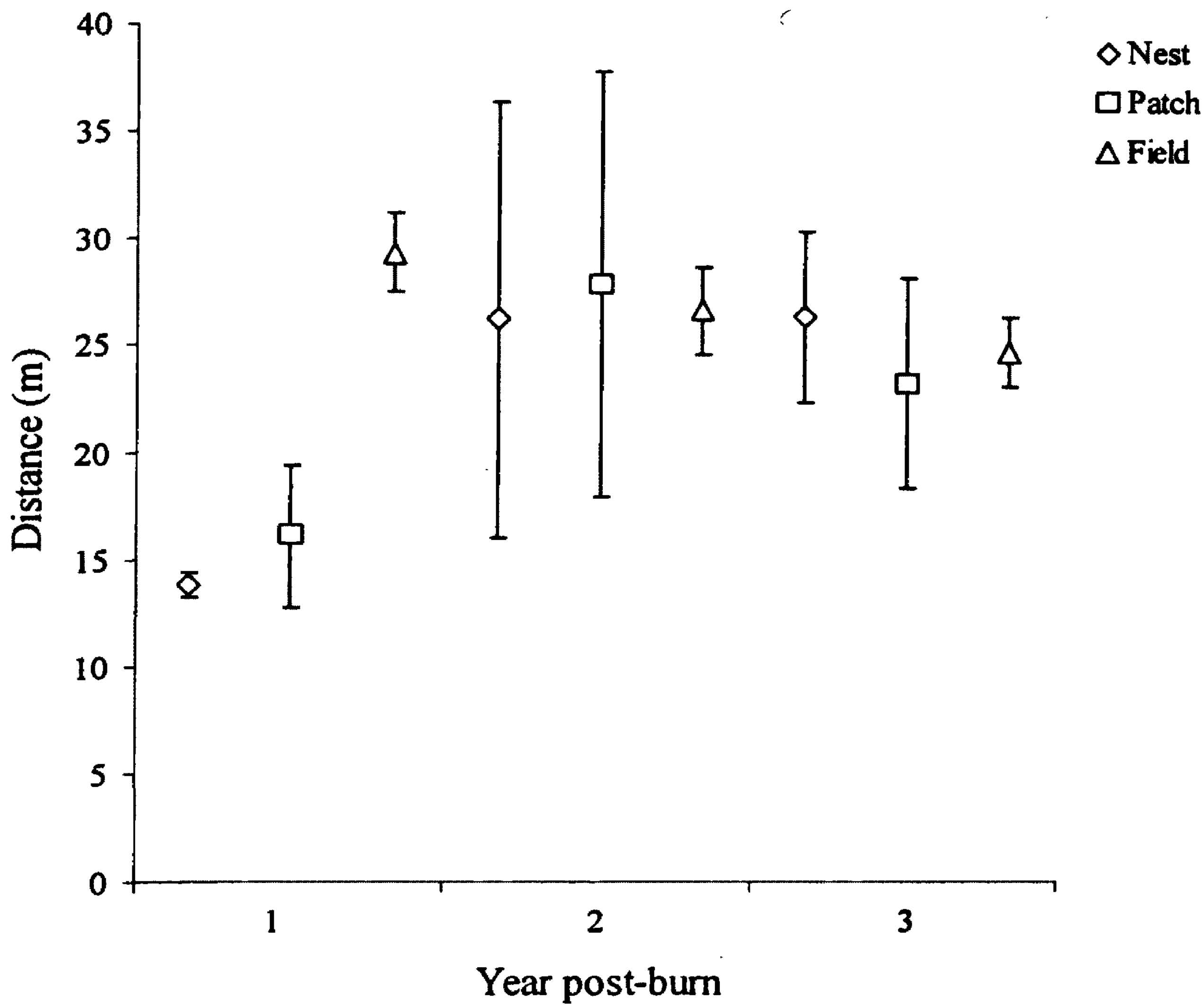

Figure 15. Mean (± SE) distance to nearest shrub at Blue-winged Teal nests, patches, and fields at J. Clark Salyer NWR in 1999-2000. Sample sizes for nest plots by year post-burn are 16, 20, 20; for patch plots are 48, 60, 60; and for field plots are 60, 60, 89.

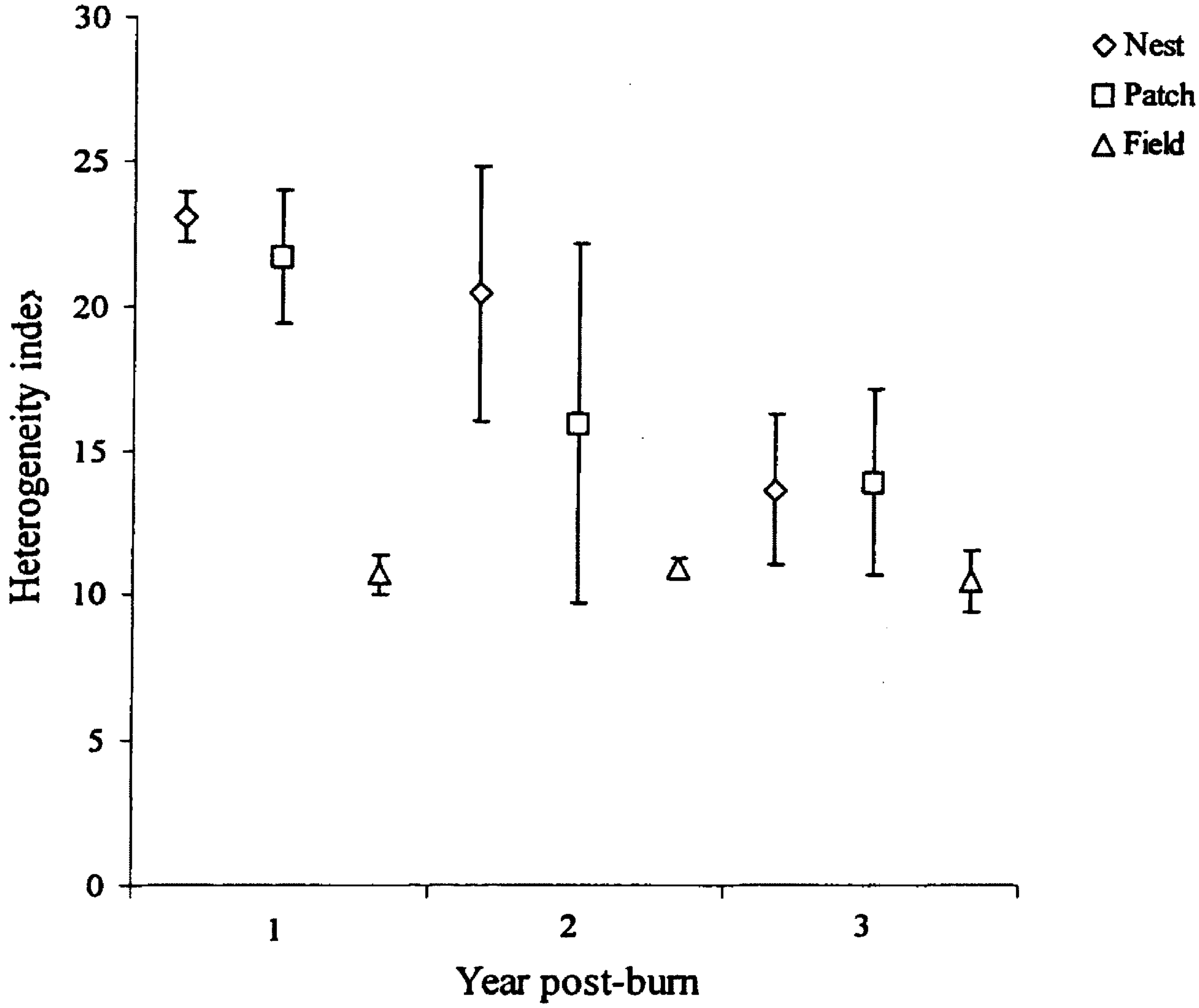

Figure 16. Mean (± SE) spatial heterogeneity index at Blue-winged Teal nest, patch, and field plots at J. Clark Salyer NWR in 1999-2000. Sample sizes for nest plots by year post-burn are 16, 20, 20; for patch plots are 48, 60, 60; and for field plots are 60, 60, 89.

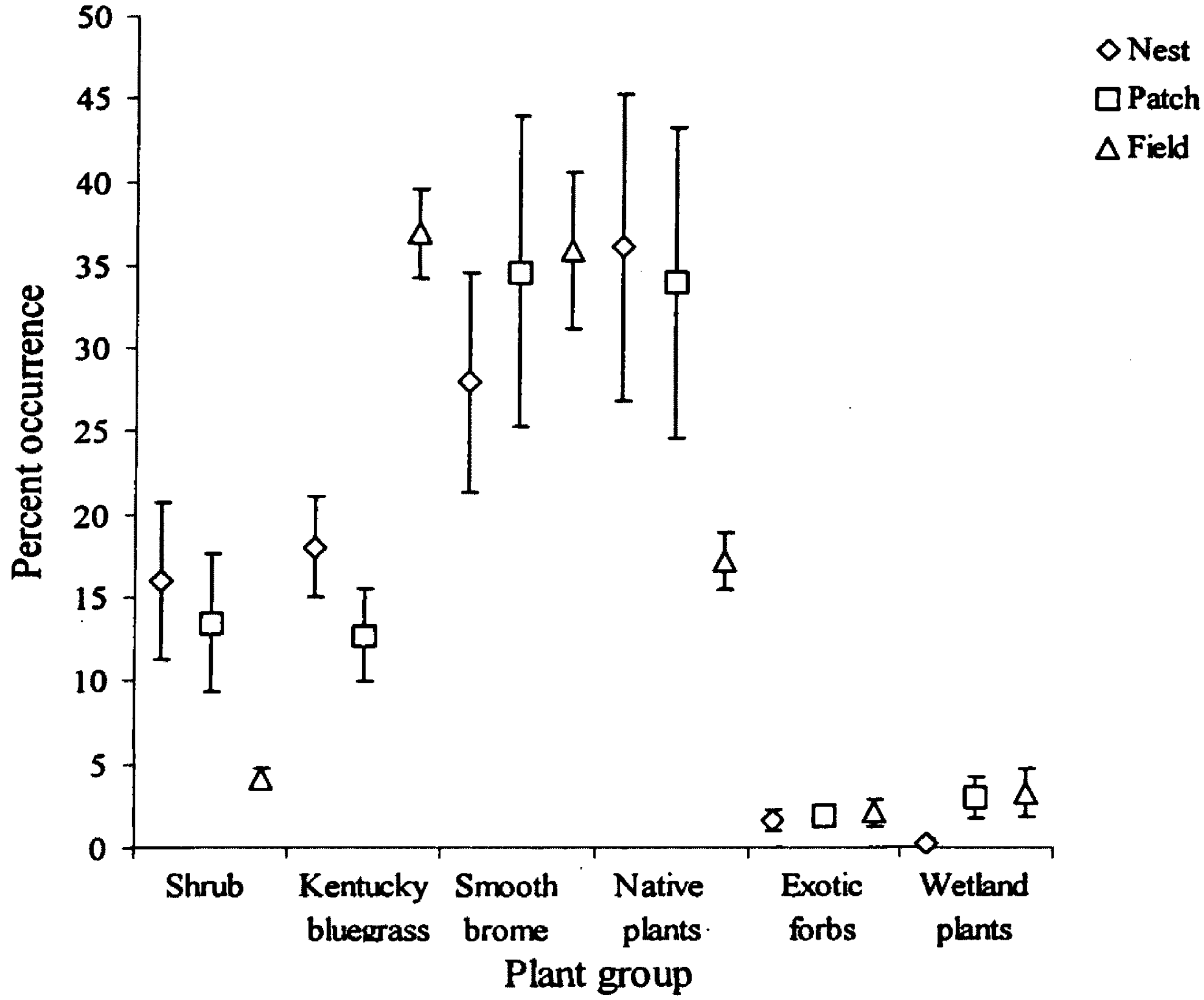

Figure 17. Mean (± SE) percent occurrence by plant group at Blue-winged Teal nests, patches, and fields at J. Clark Salyer NWR in 1999-2000. Samples size for nests is 56, for patches is 168, and for fields is 209.

DISCUSSION

Clay-Colored Sparrow

Clay-colored Sparrows selected nest sites that had greater vegetation height density, taller grass, and greater vegetation density than available within nest patches and fields. Litter depth and dead hits also were important at nest sites, as evidenced by the large differences between litter at nests and litter at patches and fields in year 1 units. By year 2 and year 3, litter and dead hits were similar to that available within patches and fields. Thus, Clay-colored Sparrow nesting may be limited in areas where burning removes all or most residual cover, even if shrubs are still available. Indeed, several studies have noted a reduction in Clay-colored Sparrow abundance following fire (Pylypec 1991, Madden 1996, Johnson 1997). Distance to nearest shrub and percent shrub cover at nest sites were much greater than in patches and in fields. Selection of relatively tall and dense vegetation with abundant residual vegetation and shrubs have characterized Clay-colored Sparrow habitat use in other studies (Knapton 1979, Dale 1983, Renken and Dinsmore 1987, Messmer 1990, Madden 1996, Schneider 1998). In my work, scale and year post-burn played a role in nest-site selection for vegetation height density, grass height, and residual vegetation cover. For nests, vegetation height density was greater at the nest bowl and 1 m than at 5m. Grass height varied by year post-burn and by scale. In year 2 and year 3 study units, nests had greater grass height than 5 m. Additionally, across all years post-burn, nests consistently had greater grass height than patches and fields. In year 1 units, litter depth and dead hits at nests decreased with distance from the nest, indicating that residual vegetation is most important immediately at the nest. Because

Clay-colored Sparrow nests are not woven around their supporting stems (Knapton 1979), nests are often resting upon and entirely supported by residual vegetation. Plant group frequency showed that Clay-colored Sparrows prefer shrubs as nest sites and also indicated that smooth brome was less suitable as a grass understory than either Kentucky bluegrass or native grasses. Madden (1996) also found that Clay-colored Sparrows showed a negative response to smooth brome and quackgrass, and suggested that this relationship may have been due to loss of snowberry to invading smooth brome.

Savannah Sparrow

Savannah Sparrows are often considered a grassland habitat generalist due to their wide geographic range and the variety of grassland types occupied (Baird 1968, Wheelwright and Rising 1993, Swanson 1998). Despite being considered a generalist, they show definite affinities for habitat use within grasslands (Tester and Marshall 1961, Dale 1983, Sample 1989, Madden 1996, Schneider 1998). Greater litter and low vegetation height density were found to be important for Savannah Sparrows where use areas were compared with non-use areas (Tester and Marshall 1961, Dale 1983, Madden 1996, Schneider 1998), and some studies have noted a preference for dense but not tall vegetation (Sample 1989, Schneider 1998). Results from my study indicate that nest-site selection follows a similar pattern: within 1 m of nests, height density was lower than at any non-nest plots, and grass height was lowest at nest plots. Selection of nest sites with greater litter and residual hits was only apparent in year 1 units, with residual vegetation at the nest bowl equaling that in year 2 and year 3 units. Additionally, variation in residual hits at the nests was nearly identical across years post-burn, indicating that Savannah

Sparrows are relatively inflexible in their ability to use habitats lacking in residual cover. These results are similar to Hoekman (1999), who found that Savannah Sparrows preferred greater low structure (vegetation density <20 cm), but lower intermediate structure (vegetation density 20-40 cm) in ungrazed, seeded grass cover in western Montana. Grass hits reflected an inverse of litter and dead hits, but by year 3, nests and nest patches had less grass hits than fields, indicating that grass was perhaps becoming too tall within the field and Savannah Sparrows had begun to select patches of shorter grass within fields.

Vegetation density differed between nests and patches, but not between nests and fields. Gotmark et al. (1995) suggested that birds select nest sites that provide a view of the surroundings, rather than sites with the greatest concealment. Lower vegetation density within the nest patch may allow Savannah Sparrows to observe approaching predators and make decisions about fleeing or hiding. Savannah Sparrow nests and patches had a greater frequency of native grasses and shrubs, and less Kentucky bluegrass and smooth brome than available in fields. This contrasts with other studies that have found Savannah Sparrows to associate with exotic grasses (Renken 1983, Madden 1996, Dale et al. 1997). However, during my study, precipitation was higher than average, and the exotic grasses (Kentucky bluegrass and smooth brome) were tall and dense. Native grasses tend to be lower growing bunchgrasses, so it is likely that Savannah Sparrows were seeking out patches of native grass that provided more appropriate structure. In drier years the sod-forming exotics may provide additional appropriate structure and litter depths for Savannah Sparrows. The presence of low shrubs (<50 cm) may provide perch sites for singing and/or foraging.

Blue-winged Teal

Blue-winged Teal showed less distinct selection of habitat at nest sites than either of the passerines in this study. Because I was able to measure Blue-winged Teal nests primarily in 2000 (53 of 56), I had fewer replicates of year post-burn for this analysis, which likely reduced my ability to assess Blue-winged Teal nest-site selection. Other studies have found that Blue-winged Teal selected shorter cover at nest sites relative to other waterfowl (Lee et al. 1964, Higgins et al. 1992, Kruse and Bowen 1996). I did not find significant differences in vegetation height at Blue-winged Teal nests; however, height density and grass height were lower than available in nest patches and field plots (Table 5). This is similar to results from western Montana, where Blue-winged Teal preferred greater vertical structure from 0-40 cm, but decreased vertical structure above 40 cm (Hoekman 1999). Litter depth did not differ between Blue-winged Teal nests, nest patches, or field plots; however, residual hits in year 1 units were greater at nests and nest patches. Thus, Blue-winged Teal may not key on litter depth per se, but rather on a minimum amount of residual cover. Kirsch et al. (1978) found that Blue-winged Teal nesting density increased as the height density of residual vegetation increased. Nests and nest patches contained a lower percentage of live grass hits than field plots. Because percent grass cover at nests is high (80%), this result reflects usage of areas with residual grass cover. Grass appears to be the favored vegetation for Blue-winged Teal nests (Lee et al. 1964, Burgess et al. 1965, Higgins et al. 1992, Clark and Shutler 1999). In year 1 units, Blue-winged Teal nests and nest patches were located closer to shrubs than were field plots. Shrubs tended to grow on mesic sites within the study area, thus the association with shrubs in year 1 units may relate to site rather than shrubs. These more mesic areas typically have increased residual vegetation and suitable cover may be provided by resprouting grass and shrubs. Plant group frequency indicated that Blue-winged Teal selected nest sites and nest patches with more native grass and shrub cover, and less Kentucky bluegrass cover than available within the field. The shrubs associated with Blue-winged Teal nests were mostly <50 cm tall (transects extended 5 m from the nest, while average distance to shrub > 50 cm was 23 m). As with Savannah Sparrows, Kentucky bluegrass was avoided, whereas native grasses were favored. During the wet years of this study, Kentucky bluegrass often exceeded 50 cm in height and was dense enough to impede a person walking through the field. In other studies, Kentucky bluegrass was a favored nesting cover (Burgess et al. 1965, Higgins et al. 1992) and would likely provide appropriate height density for nesting in a year with average precipitation. In Iowa, most Blue-winged Teal nests were found in hayfields and grazed grasslands rather than ungrazed grassland, indicating that height density on the ungrazed grassland was less suitable for nesting Blue-winged Teal (Burgess et al. 1965).

All three species showed a preference for increasing heterogeneity in the plant groups around the nest and in the nest patch. Other studies have indicated that increased spatial heterogeneity around nests can increase probability of nest success by increasing the number of potential nest sites available and/or decreasing predator search efficiency (Bowman and Harris 1980, Martin and Roper 1988, Vickery et al. 1994). The preference for increasingly heterogeneous plant communities that I observed at nests and nest patches may reflect an attempt to place nests in a safer areas.

Long-term management of plant communities to favor native prairie flora, and subsequently reduce exotic grasses would probably benefit the three species studied. A broad shift to a community dominated by native grasses could reduce the abundance of the three species I studied. A reduction in snowberry by repeated prescribed burning and grazing would likely reduce Clay-colored Sparrow abundance. Savannah Sparrows and Blue-winged Teal would likely find suitable nesting conditions in a native grass dominated community in virtually all years, although their abundance may fluctuate as moisture conditions and subsequent plant growth alter habitat structure. Dense Kentucky bluegrass appeared to provide little suitable nesting cover for any nesting birds (personal observation), and both Savannah Sparrows and Blue-winged Teal demonstrated an avoidance of Kentucky bluegrass. The preference of all three species for heterogeneous plant communities at nest sites indicates that a shift to a native floral community would be beneficial in providing suitable nesting habitat. Native plants tend to be more heterogeneous, and usually do not form monotypic stands as do Kentucky bluegrass and smooth brome.

If species are selecting nest sites based on suitable habitat characteristics, then nest characteristics should not vary by management regime, although nesting density may vary greatly based on availability of suitable characteristics (Fondell 1997). This pattern occurred in my study. Vegetation structure was changed substantially by prescribed burning, and nesting density and bird abundance was sharply reduced in year 1 units (T. Grant, unpublished data); however, conditions at nest sites were relatively consistent within the study area, even with the dramatic changes caused by prescribed burning.

Birds may respond to a combination of effects related to prescribed burning, including direct changes in vegetation structure and composition, changes in primary production and energy transfer, or indirect shifts in other organisms such as insect prey or small mammalian predators (Madden 1996). Although my study did not address factors associated with changes in food abundance or predator communities related to burning, it does support the idea that grassland birds are responding at least in part to the availability of suitable nesting sites. Grassland systems are dynamic by nature and subject to rapid changes in vegetation structure in response to precipitation patterns and management practices. If appropriate grasslands exist for a species to settle in an area (e.g. grasslands large enough to support area sensitive species [Herkert 1994, Johnson and Igl 2001]), knowledge of its nesting requirements will allow land managers to make informed decisions in managing habitat for a broader suite of species. For example, in the species I studied, nest sites differed more from habitat available in year 1 units, and by year 2, the habitat structure had recovered sufficiently to provide appropriate nesting structure for these species. By year 3, vegetation appeared to become taller and denser than suitable for Savannah Sparrows, at least during the years of above average precipitation during my study. Additionally, because selection of nest sites occurs on a relatively small scale within grasslands (Fondell 1997, Hoekman 1999, Logan 2001, this study), managers may be able to use tools (e.g. light to moderate grazing, or patchy burning or mowing) to provide habitat for a broad suite of species across the habitat spectrum, from short, sparse grass and forb dominated to taller, denser grass and shrub habitat.

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CHAPTER 3

EFFECTS OF VEGETATION STRUCTURE AND FLORISTICS ON GRASSLAND BIRD NEST SUCCESS

Recognition of predation as a major source of reproductive failure has generated interest in quantifying habitat at nests and relating vegetation characteristics to the probability of that nests produce offspring (Martin 1989). Habitat features are relatively easy to measure and may be subject to manipulation by managers attempting to improve habitat for species of interest (Best 1986). Information on relationships between nest productivity and habitat conditions may allow land managers to promote habitat conditions that maintain populations (Martin and Geupel 1993). Understanding the effects of habitat structure on nest productivity also will allow managers to weigh the short-term costs versus the long-term benefits of manipulating habitat. Documentation of nesting success under different habitat management regimes, and even basic life-history information, are lacking for many migrant species (Martin 1989). Predation often is the most important cause of nest failure for birds in grasslands (Gavin and Bollinger 1988, Kantrud and Higgins 1992, Patterson and Best 1996, Best et al. 1997, Davis and Sealy 1998). If predation has the power to affect nest-site selection, birds should choose nesting habitat that minimizes risk of predation (Martin and Roper 1988, Martin 1989). Results linking habitat features to nesting success have varied, with some studies finding differences between successful and failed nests (Martin and Roper 1988, Vickery et al. 1992, Norment 1993, Clark and Shutler 1999), and others finding either few differences or inconsistent patterns (Bedard and LaPointe 1984, Colwell 1992, Davis and Sealy 1998).

My objectives are to assess the effects of habitat structure on nest success for Savannah Sparrows (*Passerculus sandwichensis*), Clay-colored Sparrows (*Spizella pallida*), and Blue-winged Teal (*Anas discors*) by comparing habitat at successful nests with that at failed nests. Additionally, I compare a larger scale patch surrounding successful and failed nests to determine if patch complexity is higher at successful nests (Bowman and Harris 1980, Martin 1989, Vickery et al. 1994).

STUDY AREA

I measured habitat features of grassland-nesting birds at J. Clark Salyer National Wildlife Refuge (hereafter Refuge) in North Dakota from 1998-2000. The Refuge lies within the drift plain physiographic region, where the landscape is comprised of gently rolling hills with numerous wetlands (Bluemle 1991). Climate of the study area was subhumid continental, with average monthly temperatures ranging from -15° C in January to 20° C in July. Average annual precipitation from 1968-2001 was 44.60 cm, with 54% of the precipitation occurring from April to July (U.S. Fish Wildl. Serv. unpubl. data).

The grassland selected for study was 445 ha of mixed grass prairie located adjacent to the Souris River. The study area was divided into seven study units of 40 to 97 ha burned on a 3-4 year rotation. Prescribed burns were conducted in late August, after the nesting season; thus a year 1 unit was in its first growing season following fire treatment.

The vegetative community was comprised of native mixed and tall grasses, primarily wheat grasses (*Agropyron* spp.), bluestems (*Andropogon* spp.), and needle-grasses (*Stipa* spp.), with many other grasses and forbs (mostly Asteraceae and Fabaceae; Great Plains Flora Association 1986). Introduced Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermus*) are prevalent across the area. Patches of snowberry (*Symphoriocarpos occidentalis*) and the noxious weed leafy spurge (*Euphorbia esula*) are also common. Typical grassland-nesting birds in the area include Mallard (*Anas platyrhynchos*), Gadwall (*A. strepera*), Blue-winged Teal, Savannah Sparrow, Clay-colored Sparrow, and Chestnut-collared Longspur (*Calcarius ornatus*). Several other passerine species, three other waterfowl species, and two shorebird species also nested at lower densities on the study area (T. Grant, unpubl. data).

METHODS

Nests were located using 25-30 m rope drags with a can attached every 0.5 m. Rope drags were pulled by two observers, and a third observer was often used to help spot flushing birds (Davis and Sealy 1998). Each of the study units received equal search effort during the breeding season. Additional nests were located opportunistically as birds flushed during field work or were observed carrying food or nesting materials. Nests were marked with two flags placed on opposite sides of the nest, approximately 3 to 5 m from the nest. Waterfowl nests were checked every 10-14 days. Passerine nests were checked every 3-4 days during egg laying, incubation, and early nestling periods, then daily as the young neared fledging. Successful sparrow nests fledged $\geq$ 1 young, and successful duck nests hatched $\geq$ 1 egg. Unsuccessful nests fledged or hatched no young.

Vegetation measurements were taken at the nest and at three random plots within 30 m of the nest to quantify the nest patch. Nest-site and patch vegetation were measured at Savannah Sparrow nests in 1998-2000, and at Clay-colored Sparrow and Blue-winged Teal nests in 1999-2000. Vegetation at nests and patch plots was measured on the same day, within 7 days of the nest fledging young or within 7 days of the estimated fledging date for failed nests. Nest concealment was quantified using a 6.3 cm diameter disk divided radially into 8 equal black and white segments. The disk was placed horizontally in the nest, and the number of visible segments were recorded at 1 m away from the nest in each quadrant (NE, SE, SW, NW), and 1 m directly over the nest (Davis and Sealy 1998). The sum of the visible segments divided by 40 provided an index of nest concealment ranging from 1 for a completely exposed nest to 0 for a completely concealed nest. Concealment was measured both when the nest was found (early concealment) and after nest termination (late concealment).

Other vegetation measurements were taken within a 5-m radius circle centered on the nest or center of patch plots, with measures taken at the plot center, 1 m and 5 m from the center in each cardinal direction. A 7-mm diameter rod marked in cm and dm increments was used to measure litter depth and to record the number of vegetation contacts within each dm interval (each contact recorded as live grass, forb, shrub, or residual vegetation; Wiens 1969), and a Robel pole (Robel et al. 1970) was used to measure vegetation height density at each location described above. Four additional Wiens rod measurements were taken at 1 cm outside of the nest bowl in each cardinal direction and at the equivalent distance from patch centers. Total Wiens rod contacts were used as a measure of vegetation density. Distance to the nearest shrub >0.5 m tall was measured in each quadrat, providing a index of shrub dispersion. Percent ground cover was visually estimated in each quadrat of the 5 m plot, and vegetation transects were also used to assess ground cover and horizontal heterogeneity in plant communities.

I conducted statistical analyses using NCSS statistical software (Hintze 2001). To normalize data, I transformed percentage data using arcsine transformations, and other variables were transformed using log, square-root, cube-root, and reciprocal transformations. I used split-plot ANOVA to examine habitat characteristics of successful and failed nests and their respective habitat patches. In the ANOVA model, unit by year combinations were used as blocks, and within these blocks, nest plots and nest patches were used as plot level factors. Distance from plot center (measures of vegetation at the nest bowl or random plot center, 1m and 5m) was included as a subplot level factor. Blocks were nested within growing seasons post-burn (1, 2, or ≥ 3) to investigate the effects of burning on nest outcome. This model allowed me to determine which habitat features measured were related to the fate of a nest, at what local spatial scale these features operated, and how prescribed burning affected habitat features related to nest fate, while controlling for variation introduced by year and burn unit. I used Tukey-Kramer multiple comparison procedure to assess differences between means of significant interactions in each ANOVA. This test is conservative and is recommended when comparing all possible pairs (Hintze 2001). I considered $P < 0.05$ significant for post-hoc tests, results of which are presented in Appendix B.

Because ground cover composition and frequency of plant groups from transects sum to one, I used a log-ratio transformation (Aebischer et al. 1993), and conducted MANOVA on the transformed data to determine if habitat composition differed between successful and failed nests and nest patches.

RESULTS

Clay-colored Sparrow

Both successful and failed Clay-colored Sparrow nests had greater vegetation height density than their respective patch. Successful nests exhibited a greater difference from successful patches than did failed nests with failed patches at all distances, although the magnitude of the difference decreased at 5 m ($F_{6,76} = 7.43$, $P < 0.001$; Fig 1). Successful nests also showed selection for height density at a smaller scale, as height density within nest plots decreased significantly at 5 m. Percent live grass hits at the nest bowl of both successful and failed nests were lower than at patch plots ($F_{12,76} = 3.57$, $P <$ 0.001; Fig 2). In year 1 units, grass hits at successful nest bowls was markedly lower than at failed nest bowls and both patch plot centers. Successful nests had greater litter depth than successful patch plots ($F_{3,27} = 4.88$, $P = 0.008$), and non-significantly greater litter than both failed nests and failed paired plots (Table 1). Litter depth did not differ between failed nests and failed patch plots. In year 1 units, successful nests had more residual hits than failed nests ($F_{12,76} = 2.50$, $P = 0.008$; Fig 3). Additionally, residual hits at successful nests varied less across year post-burn than all other plot types. Vegetation density at nests varied by year post-burn and type of plot ($F_{6,27} = 2.89$, $P = 0.026$; Fig 4); in all years post-burn, nests exhibited greater total vegetation density than patches. Failed nests did not differ in vegetation density across burn histories, but successful nests had lower vegetation density in year 1 units than successful nests in year 2 and year 3 units. Late nest concealment was greater at successful nests than at failed nests ($F_{1,8} = 8.12$, $P =$

0.021; Table 1), but not between successful and failed nests when measured at the time the nest was found.

Savannah Sparrow

I observed few differences between successful and failed Savannah Sparrow nests (Table 2). Residual hits differed between failed nests and failed patches, but successful nests did not differ from their patches ($F_{3,43} = 10.04$, $P < 0.001$; Table 2). Vegetation density also differed between failed nests and patches, but not between successful nests and patches ($F_{3,43} = 5.58$, $P = 0.003$; Table 2). Two variables that did not produce significant ANOVA results seem biologically worthy of note: distance to nearest shrub ($F_{3,43} = 1.34$, $P = 0.28$) and early concealment ($F_{1,9} = 3.41$, $P = 0.10$) was greater at successful nests than at failed nests (Table 2).

Blue-winged Teal

None of the habitat characteristics measured at Blue-winged Teal nests varied by plot type (Table 3). Vegetation height density differed among year post-burn, plot type, and distance. Vegetation height density at successful and failed BWTE nests differed in one year and three year post-burn units ($F_{12,40} = 3.39$, $P = 0.002$; Fig 5). In year 1 units, failed nests and patches consistently had greater height density than successful nests and patches. By year 3, successful nests at the center and 1 m had much lower height density than failed nests and all patch plots.

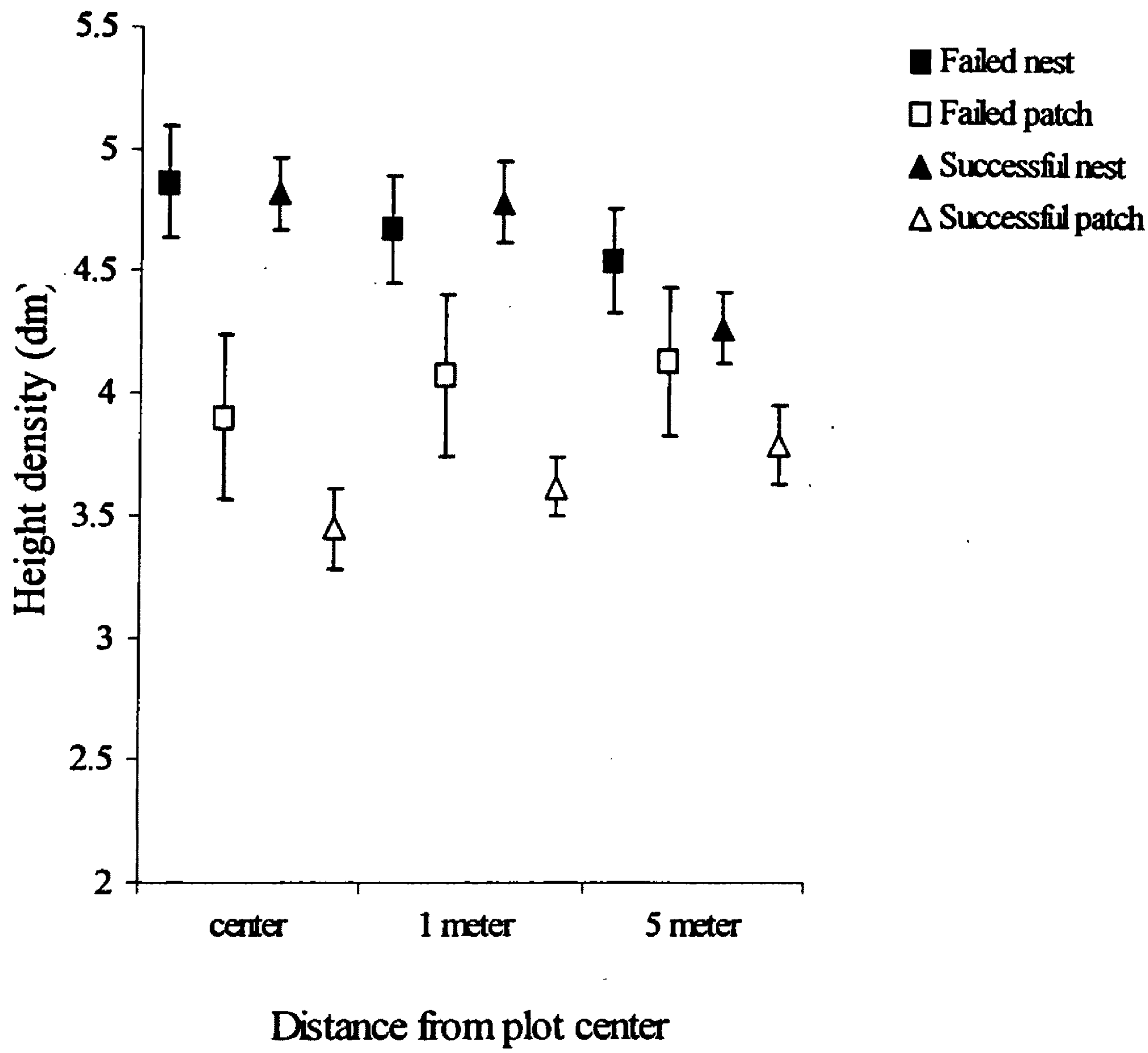

Figure 1. Mean (± SE) vegetation height density at successful and failed Clay-colored Sparrow nests and patches at J. Clark Salyer NWR in 1999-2000. Sample size for successful nests is 46, for successful patches is 138, for failed nests is 40, and for failed patches is 120.

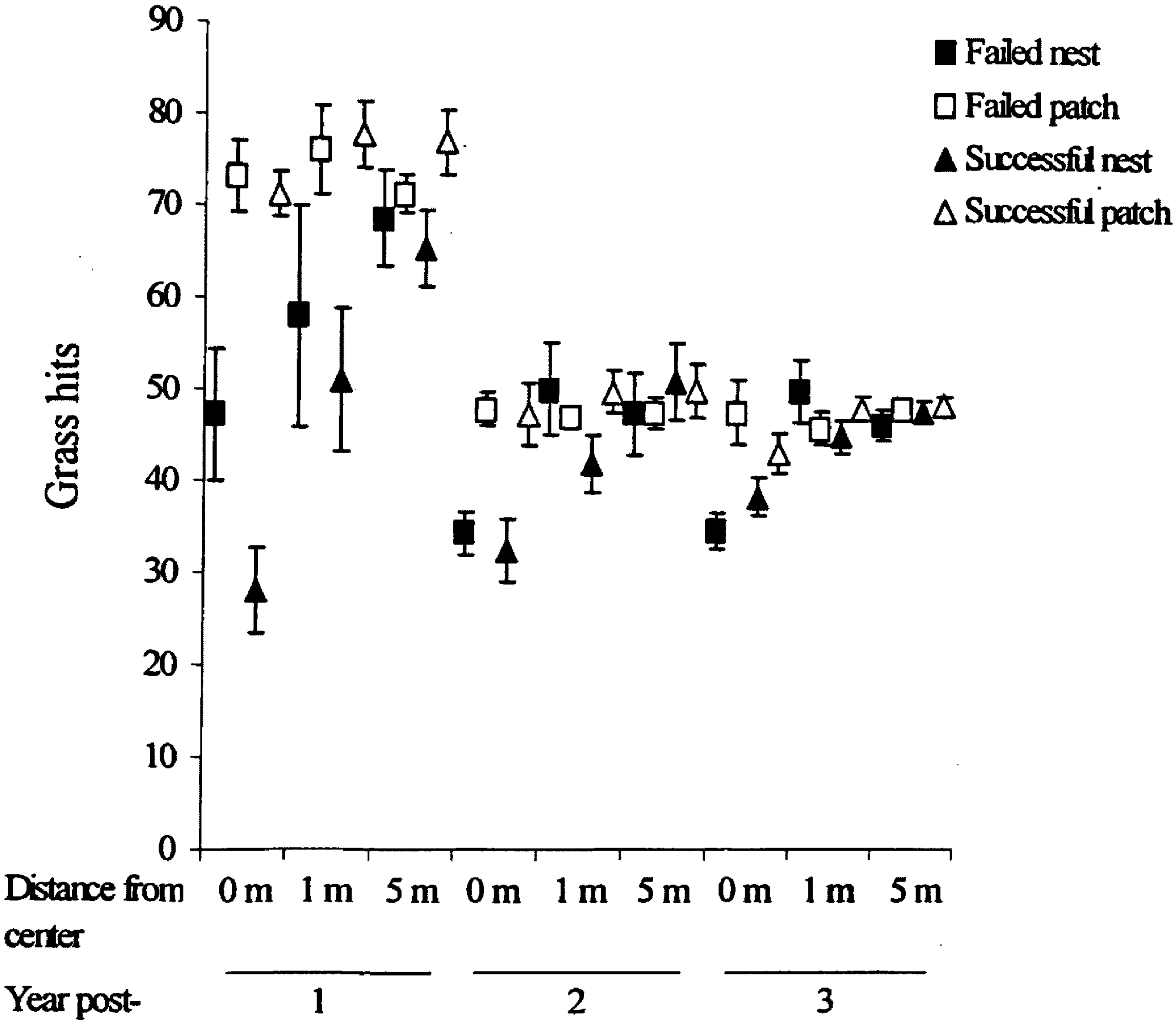

Figure 2. Mean (± SE) percent live grass hits at successful and failed Clay-colored Sparrow nests and patches at J. Clark Salyer NWR in 1999-2000. Sample sizes by year post-burn for successful nests are 14, 16, and 16; for successful patches are 42, 48, and 48; for failed nests are 10, 16, and 14; and for failed patches are 30, 48, and 42.

Table 1. Mean (SD) of habitat features measured at successful and failed Clay-colored Sparrow nests and their patch plots, 1999-2000.

Habitat Feature	Failed Nest	Failed Patch	Successful Nest	Successful Patch
Height density (dm)[a]	4.70 (0.76)	4.04 (1.10)	4.63 (0.60)	3.63 (0.54)
CV height density	21.21 (11.15)	19.38 (6.14)	20.36 (8.03)	21.97 (6.82)
Grass height (dm)	5.48 (1.09)	4.98 (1.07)	5.53 (0.75)	4.74 (0.59)
CV Grass height	22.94 (14.74)	23.44 (7.40)	24.27 (14.85)	26.91 (8.06)
Litter depth (cm)	3.24 (2.16) AB	3.27 (2.26) AB	3.61 (1.86) A	2.96 (1.92) B
Grass hits (% total)[a]	47.29 (12.48)	53.86 (12.57)	44.18 (11.04)	54.01 (12.87)
CV Grass hits	32.95 (16.52)	29.70 (14.28)	34.37 (14.48)	28.68 (12.87)
Forb hits (% total)	3.44 (2.89)	4.73 (2.17)	2.75 (2.72)	4.81 (3.52)
CV Forb hits	101.57 (54.06)	97.35 (38.17)	87.10 (56.46)	100.89 (36.76)
Residual hits[a]	5.85 (1.84)	5.35 (2.19)	6.31 (1.63)	5.48 (2.45)
CV Residual hits	33.50 (13.65)	41.21 (20.34)	32.72 (14.16)	43.00 (27.52)
Vegetation Density[a]	274.52 (35.85)	218.33 (41.94)	270.51 (41.78)	222.83 (44.08)
Dist. to Shrub (m)	1.22 (1.63) A	12.49 (6.04) B	1.32 (1.70) A	13.45 (4.45) B
CV Dist to Shrub	77.18 (17.95)AB	64.63 (13.46)A	81.41 (21.53)B	67.53 (10.81)AB
Heterogeneity Index	16.30 (4.79)	15.56 (6.51)	18.11 (5.85)	18.14 (6.00)

Table 1. Continued.

Late concealment	14.56 (5.53) A	9.81 (3.59) B
CV Late concealment	141.11 (41.30)	163.52 (31.73)
Early concealment	16.27 (8.62)	14.10 (4.43)
CV Early concealment	115.80 (65.89)	136.60 (43.44)
Nest Height	0.21 (0.08)	0.19 (0.03)

[a] Denotes significant interaction for this variable. Results of post-hoc tests are presented in Appendix B.

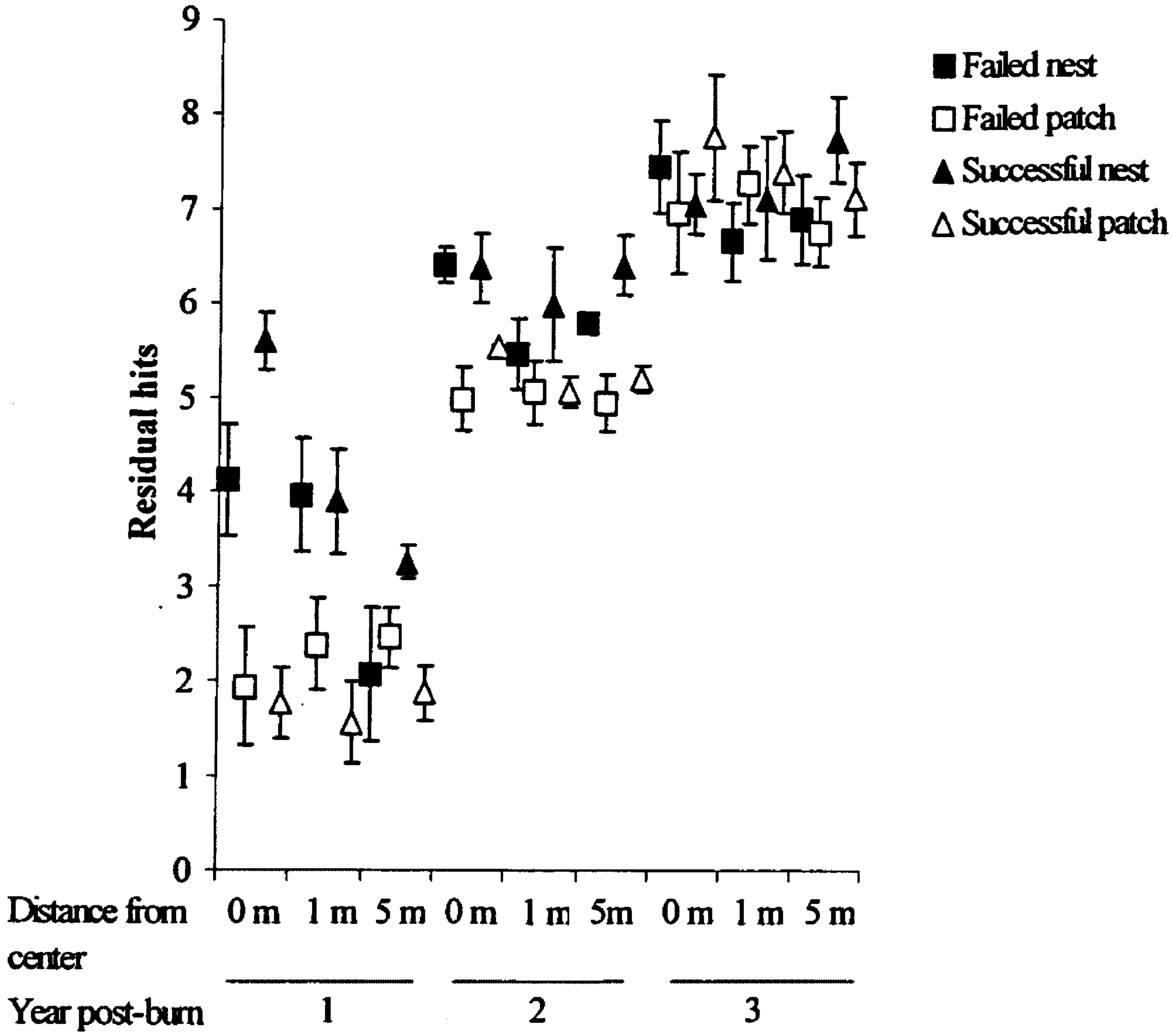

Figure 3. Mean (+ SE) residual herbaceous hits in 1st dm at successful and failed Clay-colored Sparrow nests and patches at J. Clark Salyer NWR in 1999-2000. Sample sizes by year post-burn for successful nests are 14, 16, and 16; for successful patches are 42, 48, and 48; for failed nests are 10, 16, and 14; and for failed patches are 30, 48, and 42.

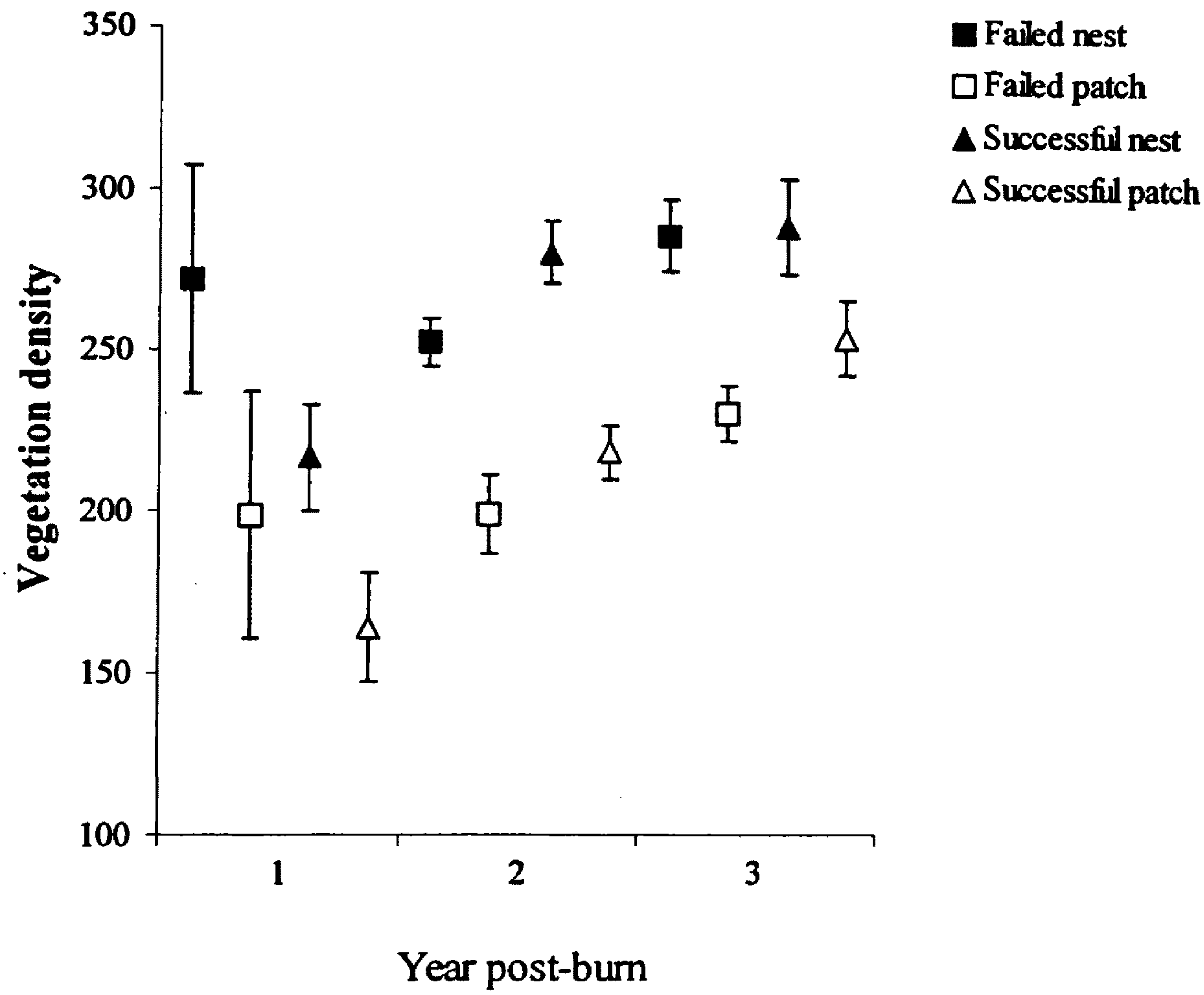

Figure 4. Mean (+ SE) vegetation density at successful and failed Clay-colored Sparrow nests and patches at J. Clark Salyer NWR in 1999-2000. Sample sizes by year post-burn for successful nests are 14, 16, and 16; for successful patches are 42, 48, and 48; for failed nests are 10, 16, and 14; for failed patches are 30, 48, and 42.

Table 2. Mean (SD) of habitat features measured at successful and failed Savannah Sparrow nests and patch plots at J. Clark Salyer NWR, 1998-2000.

Habitat Feature	Failed Nest	Failed Patch	Successful Nest	Successful Patch
Height density (dm)	2.79 (1.03)	2.71 (0.79)	2.73 (0.73)	3.00 (0.90)
CV Height density	24.34 (1.21)	24.49 (0.89)	24.87 (1.23)	23.67 (0.99)
Grass height (dm)	3.77 (0.88)	3.90 (0.88)	3.83 (0.69)	4.09 (0.79)
CV Grass height	33.81 (2.06)	31.38 (1.08)	30.67 (1.61)	28.59 (1.16)
Litter depth (cm)	3.02 (1.79)	2.67 (1.97)	2.84 (1.64)	2.65 (1.64)
Grass hits	45.46 (18.47)	51.26 (20.18)	47.33 (14.51)	51.76 (15.38)
CV Grass hits	36.48 (20.86)	36.41 (19.25)	37.31 (15.14)	32.46 (14.25)
Forb hits	3.88 (3.57)	4.41 (3.09)	4.23 (4.33)	3.35 (2.23)
CV Forb hits	100.39 (56.05)	91.53 (32.15)	82.97 (53.96)	90.69 (32.34)
Residual hits	5.84 (2.63) A	4.89 (2.78) C	5.66 (2.31) AB	5.27 (2.34) BC
CV Residual hits	50.30 (4.89)	56.52 (4.47)	49.15 (4.93)	51.87 (3.93)
Vegetation Density	189.50 (38.90)A	166.93 (41.23)B	189.35 (26.46)A	177.75 (33.82)AB
Distance to Shrub	18.46 (9.01)	21.51 (7.17)	27.98 (16.83)	26.06 (16.41)
CV Distance to Shrub	65.97 (14.46)	60.17 (14.23)	56.37 (21.57)	61.39 (14.77)
Heterogeneity Index	15.12 (7.26)	14.40 (5.09)	14.56 (6.17)	13.88 (6.19)

Late concealment	25.43 (12.91)	21.83 (12.69)
CV Late concealment	126.04 (37.70)	143.97 (34.05)
Early concealment	24.71 (11.35)	15.70 (8.09)
CV Early concealment	110.91 (43.30)	114.69 (40.24)

Table 3. Mean (SD) of habitat features measured at successful and failed Blue-winged Teal nests and patch plots at J. Clark Salyer NWR, 1999-2000.

Habitat Feature	Failed Nest	Failed Patch	Successful Nest	Successful Patch
Height density (dm)[a]	3.36 (1.04)	3.53 (1.04)	2.96 (0.98)	3.46 (0.97)
CV Height density	23.53 (6.36)	23.18 (8.50)	29.38 (15.13)	24.86 (10.83)
Grass height (dm)	4.47 (1.01)	4.48 (0.74)	4.18 (0.98)	4.40 (0.92)
CV Grass height	31.10 (13.89)	27.49 (6.41)	34.68 (15.25)	29.38 (10.15)
Litter depth (cm)	2.28 (1.70)	2.24 (1.97)	1.20 (0.77)	1.14 (0.65)
Grass hits	50.41 (12.33)	51.65 (11.80)	51.60 (11.41)	48.41 (7.96)
CV Grass hits	33.26 (14.40)	31.87 (8.55)	39.51 (19.50)	36.28 (11.73)
Forb hits	4.03 (3.66)	3.88 (2.33)	4.63 (3.99)	6.64 (6.19)
CV Forb hits	94.79 (53.81)	88.15 (29.17)	94.94 (71.82)	89.11 (47.79)
Residual hits	5.31 (1.76)	5.10 (2.16)	4.54 (2.12)	4.77 (2.06)
CV Residual hits	44.73 (13.46)	43.00 (14.35)	56.14 (22.96)	44.81 (15.53)
Vegetation Density	210.66 (24.87)	198.94 (49.58)	202.44 (60.60)	185.35 (55.17)
Distance to Shrub	20.26 (9.76)	21.15 (9.09)	23.85 (19.82)	25.46 (16.73)
CV Distance to Shrub	74.00 (16.47)	64.64 (11.94)	64.06 (32.66)	67.64 (10.64)
Heterogeneity Index	19.74 (8.32)	16.70 (7.40)	19.83 (6.86)	20.41 (6.43)

Late concealment	44.94 (13.17)	46.26 (22.76)
CV Late concealment	93.34 (42.69)	98.79 (47.59)
Early Concealment	34.52 (15.20)	36.88 (13.12)
CV Early Concealment	94.86 (31.67)	102.00 (20.83)

[a] Denotes significant interaction for this variable. Results of post-hoc tests are presented in Appendix B.

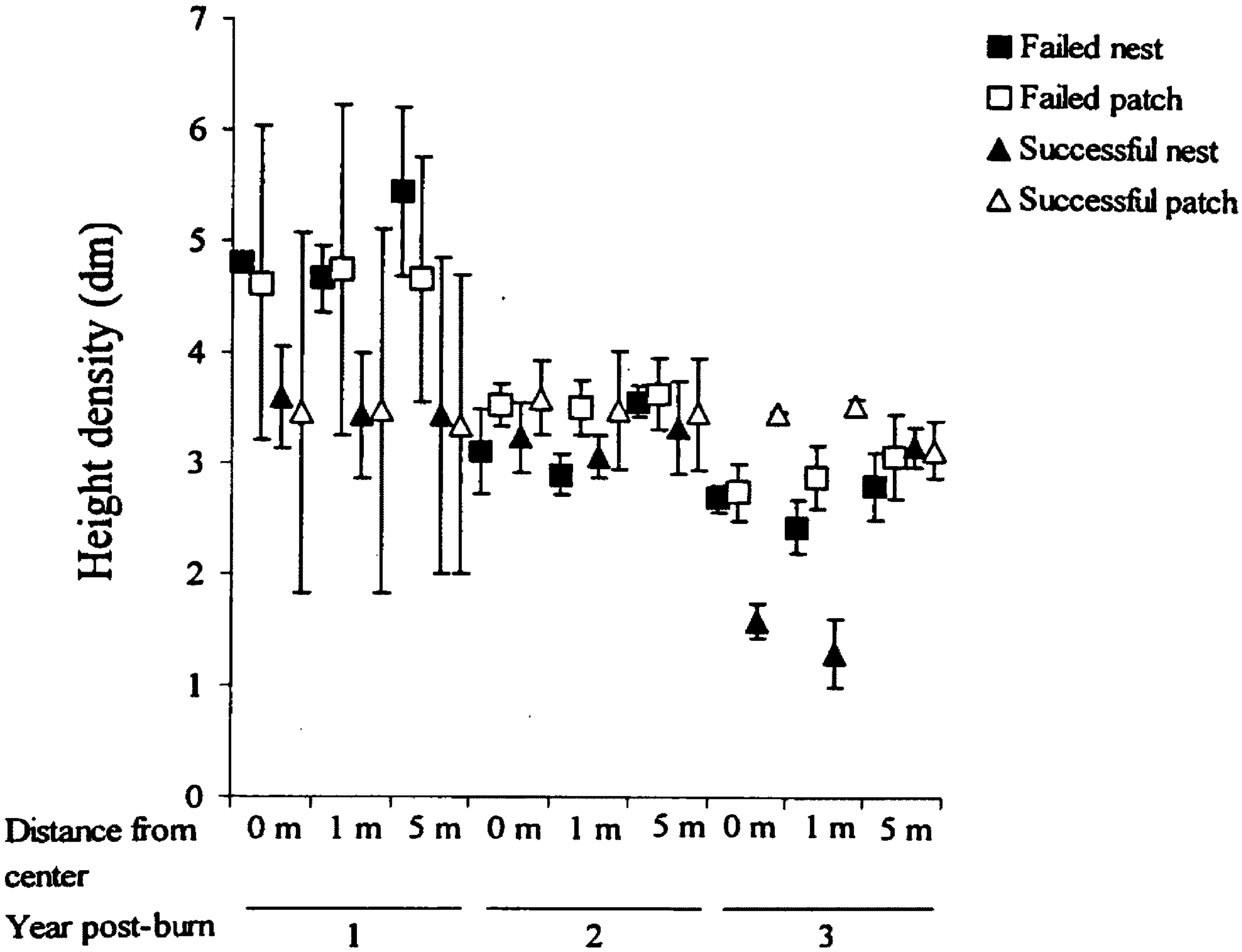

Figure 5. Mean (± SE) vegetation height density at successful and failed Blue-winged Teal nests and patches at J. Clark Salyer NWR in 1999-2000. Samples sizes by year post-burn for successful nests are 8, 12, 3; for successful patches are 24, 36, 9; for failed nests are 8, 8, 17; and for failed patches are 24, 24, 51.

DISCUSSION

Clay-colored Sparrow

Vegetation height density was greater at successful and failed nests than at patches, but the difference between nest and patch was greater for successful nests. In addition, successful nests were in smaller patches of tall vegetation than were failed nests. Predation on passerine nests may result primarily from incidental contacts by predators foraging for other foods (Vickery et al. 1992, Yanes and Suarez 1996). Some predators may actively search patches of tall vegetation for waterfowl nests (Crabtree et al. 1989). Thus, Clay-colored Sparrow nests in small patches of tall vegetation may be less likely to be encountered by a predator actively searching tall cover for waterfowl nests. Successful nests year 1 units had lower live grass hits, and greater litter depth and dead hits than failed nests and nest patches. Knapton (1979) found that successful Clay-colored Sparrow nests had less light penetration and were closer to the ground than failed nests, and suggested that this combination would effectively hide the nest silhouette. The increased litter and dead hits I observed at successful nests may likewise conceal the nest bowl from ground-based predators such as mice or ground squirrels.

One way birds may avoid nest predation is to nest in areas with many potential nest sites, thus reducing predator efficiency (Martin and Roper 1988). Vegetation density at successful nests in year 1 units were more similar to nest patches than failed nests, and successful nests differed across year post-burn, while failed nests did not. Because vegetation density is reduced following fire, nesting in vegetation that is similar to that available may increase the probability of fledging young. Late concealment was higher at successful nests, and increased from the early concealment. Because parental activity at the nest and predation rates increase with nestling age (Pietz and Granfors 2000), increasing concealment may have served to conceal adult movements as they tended nestlings, and made the nestlings less visible to predators.

Savannah Sparrow

Few habitat characteristics differed between successful and failed nests of Savannah Sparrows. Both residual hits and vegetation density were similar between successful nests and successful patches, but failed nests differed from their respective patch. In Arizona, nest success of Hermit Thrushes (*Catharus guttatus*) was higher in patches with higher densities of small white firs (*Abies concolor*). The increased availability of suitable nest sites offered by high fir density could reduce predator efficiency in finding actual nests (Martin and Roper 1988). Because successful Savannah Sparrow nests were surrounded by vegetation with residual hits and vegetation density that would likely be suitable for nesting, predators may be less efficient in finding these nests. Although distance to nearest shrub did not differ between successful and failed nests, both successful nests and patches were farther from shrubs than failed nests and patches. Other studies utilizing artificial nests and natural nests have found that nests closer to shrubs experienced greater predation (Johnson and Temple 1986, Burger et al. 1994, McKee et al. 1998). Early concealment was greater at successful nests than failed nests, suggesting that concealment of the attending parent may be important.

Blue-winged Teal

Vegetation height density was greater at failed nests and patches in year 1 units, but successful nests and patches were more similar to height density of field plots. Vigorous regrowth in the first year following prescribed burning may have been appealing to Blue-winged Teal as there was little residual vegetation remaining in these units; however, these taller patches of vegetation may have attracted mammalian predators. By year 3, successful Blue-winged Teal nests had much lower vegetation height density than failed nests and both successful and failed patches. By using shorter vegetation for nesting, successful Blue-winged Teal may be avoiding vegetation supporting a higher density of nesting ducks that may attract predators (Crabtree et al. 1989).

Other studies have found that nest-site selection is a non-random process, yet have found few differences between successful and failed nests (Schroeder and Braun 1992, Colwell 1992, Wilson and Cooper 1998, Ricketts and Ritchison 2000). In my study, all three species selected habitat features non-randomly but exhibited fewer differences between successful and failed nests. Habitat structure by itself is often an unreliable predictor of predation and nest success, which may be better defined by activity budgets of individuals, resource availability (Morrison 2001), or limitations imposed by reduction in available space and inadequate time to change habitat selection in response to altered landscapes. One problem that many species currently face is that habitat preferences shaped by their evolutionary histories may not be appropriate under current landscape conditions (Martin 1992). Changes in the predator community in the northern Great Plains may have altered predation pressures on ground nesting birds such that nest-site selection may not provide a safe haven from predators. Crooks and Soule (1999) found that declines in coyotes (*Canis latrans*) in southern California led to increases in raccoon

(*Procyon lotor*), domestic cat (*Felis domesticus*), and opossum (*Didelphis virginianus*) activity, and that domestic cat predation on scrub-breeding birds was high enough to create an unsustainable population. Other studies have found nest success to increase when coyotes were present in the area, and suggest that negative effects of coyotes on red fox (*Vulpes vulpes*) and raccoon populations led to improved nest success (Sovada et al. 1995, Rogers and Caro 1998). Additionally, some studies have reported evidence of incidental nest predation (Vickery et al. 1992, Yanes and Suarez 1996), where nests are encountered fortuitously while foraging for other prey. Other factors such as flushing behavior and nest defense by adults, crypsis, and their interactions with nest-site habitat may also be important in determining probability of nest success (Burhans and Thompson 2001). Thus, although I noted several habitat characteristics that differed between successful and failed nests, it remains likely that vegetation characteristics per se cannot solely predict nest fate.

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APPENDIX A

POST-HOC TEST RESULTS FOR CHAPTER 2

Table 1. Interaction between type and distance for height density (dm) measures at Clay-colored Sparrow nest plots, patch plots, and field plots at J. Clark Salyer NWR, 1999-2000. Within rows, columns with different letters indicate significant differences ($q = 4.54$, df = 66, $P \leq 0.05$).

Distance	Plot Type		
	Nest	Patch	Field
Nest bowl/center	4.89 (0.49) A	3.72 (0.70) B	3.37 (0.33) C
1m	4.78 (0.52) A	3.89 (0.67) B	3.47 (0.34) C
5m	4.38 (0.49) A	3.98 (0.72) B	3.44 (0.39) C

Plot Type	Distance		
	Nest bowl/center	1m	5m
Nest	4.89 (0.49) A	4.78 (0.52) A	4.38 (0.49) B
Patch	3.72 (0.70) A	3.89 (0.67) AB	3.98 (0.72) B
Field	3.37 (0.33)	3.47 (0.34)	3.44 (0.39)

Table 2. Interaction between type and distance for CV height density at Clay-colored Sparrow nest, patch, and field plots at J. Clark Salyer NWR, 1999-2000. Within rows, columns with different letters indicate significant differences ($q = 4.54$, df = 66, $P \leq 0.05$).

Distance	Plot Type		
	Nest	Patch	Field
Nest bowl/center	14.11 (4.26) A	16.91 (2.31) B	16.78 (3.79) AB
1 meter	19.48 (5.32)	19.50 (3.61)	21.06 (4.32)
5 meter	27.86 (8.30)	25.89 (6.25)	26.88 (6.10)

Plot Type	Distance		
	Nest bowl/center	1 meter	5 meter
Nest	14.11 (4.26) A	19.48 (5.32) B	27.86 (8.30) C
Patch	16.91 (2.31) A	19.50 (3.61) A	25.89 (6.25) B
Field	16.78 (3.79) A	21.06 (4.32) B	26.88 (6.10) C

Table 3. Interaction between year post-burn, plot type, and distance from plot center for grass height (dm) at Clay-colored Sparrow nest, patch, and field plots at J. Clark Salyer NWR, 1999-2000. Within rows, columns with different letters indicate significant differences.

	Plot Type		
Year post-burn, distance	Nest	Patch	Field
1, Nest bowl	5.59 (1.75)	5.25 (1.38)	5.05 (0.63)
1, 1 meter	5.65 (1.17)	5.27 (1.22)	5.03 (0.45)
1, 5 meter	5.80 (1.14)	5.29 (1.25)	4.72 (0.34)
2, Nest bowl [a]	5.53 (0.59) A	4.36 (0.22) AB	4.19 (0.34) B
2, 1 meter	5.32 (0.48)	4.47 (0.19)	4.37 (0.23)
2, 5 meter	4.66 (0.27)	4.67 (0.51)	4.21 (0.31)
3, Nest bowl [b]	5.79 (0.39) A	4.62 (0.46) B	4.61 (0.48) B
3, 1 meter	5.55 (0.54)	4.77 (0.34)	4.54 (0.43)
3, 5 meter	5.21 (0.39)	4.90 (0.28)	4.71 (0.32)

Year post-burn, Type	Distance		
	Nest bowl/center	1 meter	5 meter
2, Nest [c]	5.53 (0.59) A	5.32 (0.48) AB	4.66 (0.27) B

[a] Nest to field, $q = -3.96$, df = 66, $P = 0.037$

[b] Nest to patch, $q = 4.12$, df = 66, $P = 0.023$; nest to field, $q = -4.08$, df = 66, $P = 0.026$

[c] Nest bowl to 5 meter, $q = 3.70$, df = 66, $P = 0.077$

Table 4. Interaction between year post-burn, plot type, and distance from plot center for litter depth (cm) at Clay-colored Sparrow nest, patch, and field plots at J. Clark Salyer NWR, 1999-2000. Within rows, columns with different letters indicate significant differences.

	Plot Type		
Year post-burn, distance	Nest	Patch	Field
1, Nest bowl [a]	1.57 (0.98) A	0.48 (0.29) B	0.36 (0.20) B
1, 1 meter	1.27 (0.88)	0.51 (0.26)	0.37 (0.17)
1, 5 meter	0.76 (0.38)	0.55 (0.26)	0.42 (0.15)
2, Nest bowl	4.60 (3.35)	3.02 (1.64)	2.35 (1.35)
2, 1 meter	2.93 (1.62)	2.82 (1.66)	2.20 (1.35)
2, 5 meter	3.66 (1.22)	2.82 (1.35)	2.28 (1.20)
3, Nest bowl	4.09 (1.87)	4.36 (1.65)	3.82 (1.17)
3, 1 meter	3.82 (1.23)	4.30 (1.47)	3.76 (1.34)
3, 5 meter	4.19 (0.93)	4.10 (1.29)	4.10 (1.04)

Year post-burn, Type	Distance		
	Nest bowl/center	1 meter	5 meter
1, Nest [b]	1.57 (0.98) A	1.27 (0.88) AB	0.76 (0.38) B

Plot Type, Distance	Year Post-burn		
	1	2	3
Nest, Nest bowl [c]	1.57 (0.98)	4.60 (3.35)	4.09 (1.87)
Nest, 1 meter [d]	1.27 (0.88) A	2.93 (1.62) AB	3.82 (1.23) B

[a] Nest bowl to patch center, $q = 4.25$, df = 66, $P = 0.016$; Nest bowl to field center, $q = -5.38$, df = 66, $P < 0.001$

[b] Nest bowl to 5 meter, $q = 4.88$, df = 66, $P = 0.002$

[c] No significant differences among year post-burn, $q = -2.84$ and -3.18, df = 66, $P > 0.260$

[d] One year post-burn to three year post-burn, $q = -3.93$, df = 66, $P = 0.041$. For all other plot type by distance combinations, year 1 post-burn differed from both year 2 and year 3 post-burn, all $q \geq 4.47$, df = 66, $P < 0.01$.

Table 5. Interaction between year post-burn, plot type, and distance from plot center for residual hits in the first dm at Clay-colored Sparrow nest, patch, and field plots at J. Clark Salyer NWR, 1999-2000. Within rows, columns with different letters indicate significant differences.

	Plot Type		
Year post-burn, distance	Nest	Patch	Field
1, Nest bowl [a]	4.59 (1.33) A	1.74 (0.69) B	1.48 (0.52) B
1, 1 meter [b]	3.65 (1.35) A	1.82 (0.65) AB	1.55 (0.45) B
1, 5 meter	2.55 (0.97)	1.89 (0.61)	1.67 (0.34)
2, Nest bowl	6.25 (0.57)	5.39 (0.25)	5.13 (1.10)
2, 1 meter	5.65 (0.94)	5.09 (0.28)	4.88 (1.14)
2, 5 meter	6.14 (0.23)	5.11 (0.19)	4.88 (1.11)
3, Nest bowl	6.97 (0.78)	7.36 (1.17)	6.82 (1.11)
3, 1 meter	6.99 (0.78)	7.36 (0.85)	6.55 (1.03)
3, 5 meter	7.17 (0.56)	6.99 (0.75)	6.62 (0.81)
Year post-burn, Type	Distance		
	Nest bowl/center	1 meter	5 meter
1, Nest [c]	4.59 (1.33) A	3.65 (1.35) B	2.55 (0.97) C
Plot Type, Distance	Year Post-burn [e]		
	1	2	3
Nest, Nest bowl [d]	4.59 (1.33) A	6.25 (0.57) AB	6.97 (0.78) B
Nest, 1 meter [d]	3.65 (1.35) A	5.65 (0.94) AB	6.99 (0.78) B
Nest, 5 meter [d]	2.55 (0.97) A	6.14 (0.23) B	7.17 (0.56) B

[a] Nest to patch, $q = 5.20$, df = 66, $P < 0.001$; Nest to field, $q = -5.68$, df = 66, $P < 0.001$.

[b] Nest to field, $q = -3.81$, df = 66, $P = 0.057$

[c] Nest bowl to 1 m, $q = 4.26$, df = 66, $P = 0.015$; nest bowl to 5 m, $q = 9.20$, df = 66, $P < 0.001$

[d] Nest bowl, $q = -4.36$, df = 66, $P = 0.011$; 1 m, $q = -6.14$, df = 66, $P < 0.001$, 5 m, $q = -8.49$, df = 66, $P < 0.001$

[e] For patch and field plots, year 1 post-burn differed from both year 2 and year 3 post-burn at all distances (all $q \geq 5.38$, df = 66, $P < 0.001$).

Table 6. Interaction between year post-burn, plot type, and distance from plot center for percent grass hits at Clay-colored Sparrow nest, patch, and field plots at J. Clark Salyer NWR, 1999-2000. Within rows, columns with different letters indicate significant differences.

	Plot Type		
Year post-burn, distance	Nest	Patch	Field
1, Nest bowl [a]	37.20 (15.72) A	74.10 (7.68) B	80.11 (5.77) B
1, 1 meter [b]	54.56 (16.40) A	78.04 (6.34) B	81.68 (6.19) B
1, 5 meter	67.87 (8.89)	74.95 (3.19)	78.43 (5.53)
2, Nest bowl	33.51 (4.86)	46.53 (6.20)	56.00 (2.14)
2, 1 meter	44.58 (7.19)	48.79 (3.31)	56.89 (4.03)
2, 5 meter	50.67 (8.68)	49.79 (4.65)	58.40 (1.19)
3, Nest bowl	36.25 (2.93)	45.63 (4.68)	52.28 (3.99)
3, 1 meter	45.55 (2.01)	46.61 (3.06)	53.02 (3.72)
3, 5 meter	46.59 (2.50)	48.24 (1.52)	52.90 (4.07)
Year post-burn, Type	Distance		
	Nest bowl/center	1 meter	5 meter
1, Nest [c]	37.20 (15.72) A	54.56 (16.40) B	67.87 (8.89) C
2, Nest [c]	33.51 (4.86) A	44.58 (7.19) B	50.67 (8.68) B
3, Nest [c]	36.25 (2.93) A	45.55 (2.01) B	46.59 (2.50) B
Plot Type, Distance	Year Post-burn [e]		
	1	2	3
Nest, Nest bowl [d]	37.20 (15.72)	33.51 (4.86)	36.25 (2.93)
Nest, 1 meter [d]	54.56 (16.40)	44.58 (7.19)	45.55 (2.01)

[a] Nest to patch, $q = -9.03$, df = 66, $P < 0.001$; Nest to field, $q = 10.46$, df = 66, $P < 0.001$
[b] Nest to patch, $q = -5.60$, df = 66, $P < 0.001$; Nest to field, $q = 6.78$, df = 66, $P < 0.001$
[c] For all three year post-burn by nest combination, percent grass at the nest bowl differed from percent grass at 1 meter and 5 meters, all $q > 4.69$, df = 66, $P < 0.01$.
[d] For nests at the bowl and 1 meter, percent grass did not differ across year post-burn, all $q \leq 2.13$, df = 66, $P \geq 0.917$.
[e] For nests at 5 meter, and all distances of nest patches and field plots, year 1 post-burn plots differed from both year 2 and year 3 post-burn plots, all $q \geq 4.64$, df = 66, $P < 0.01$, except nest, 5 meter differed at q = 3.75, df = 66, $P = 0.068$.

Table 7. Interaction between plot type and distance from nest bowl/plot center for height density (dm) at Savannah Sparrow nest, patch, and field plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences ($q = 4.54$, df = 66, $P \leq 0.05$)

Distance	Plot Type		
	Nest	Patch	Field
Nest bowl/center	3.07 (0.48) A	3.23 (0.43) AB	3.37 (0.33) B
1 meter	3.04 (0.46) A	3.39 (0.38) B	3.47 (0.34) B
5 meter	3.26 (0.48)	3.37 (0.46)	3.44 (0.39)

Plot Type	Distance		
	Nest bowl/center	1 meter	5 meter
Nest	3.07 (0.48) AB	3.04 (0.46) A	3.26 (0.48) B
Patch	3.23 (0.43)	3.39 (0.38)	3.37 (0.46)
Field	3.37 (0.33)	3.47 (0.34)	3.44 (0.39)

Table 8. Interaction between year post-burn, plot type, and distance from nest bowl/center for litter depth (cm) at Savannah Sparrow nest, patch, and field plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences. All post hoc tests have 66 df.

Year post-burn, distance	Plot Type		
	Nest	Patch	Field
1, Nest bowl/center [a]	2.36 (0.10) A	0.41 (0.05) B	0.36 (0.20) B
1, 1meter [b]	0.63 (0.86) A	0.48 (0.12) AB	0.37 (0.17) B
1, 5meter	0.74 (0.21)	0.56 (0.29)	0.42 (0.15)
2, Nest bowl/center	2.55 (0.87)	2.21 (1.05)	2.35 (1.35)
2, 1meter	2.21 (1.29)	2.38 (1.03)	2.20 (1.35)
2, 5 meter	2.01 (1.14)	2.34 (0.98)	2.28 (1.20)
3, Nest bowl	4.04 (1.40)	3.47 (1.35)	3.82 (1.17)
3, 1meter	3.66 (1.73)	3.45 (1.51)	3.76 (1.34)
3, 5meter	3.96 (1.20)	3.65 (1.36)	4.10 (1.04)

Year post-burn, Type	Distance		
	Nest bowl/center	1 meter	5 meter
1, Nest [c]	2.36 (0.10) A	0.63 (0.86) B	0.74 (0.21) B

Plot Type, Distance	Year Post-burn [f]		
	1	2	3
Nest, nest bowl [d]	2.36 (0.10)	2.55 (0.87)	4.04 (1.40)
Nest, 1 meter [e]	0.63 (0.86) A	2.21 (1.29) AB	3.66 (1.73) B
Nest, 5 meter [e]	0.74 (0.21) A	2.01 (1.14) AB	3.96 (1.20) B

[a] Nest to patch, $q = 10.52$, $P < 0.001$; Nest to field, $q = 12.49$, $P < 0.001$
[b] Nest to field, $q = 3.79$, $P = 0.060$
[c] Nest bowl to 1 meter, $q = 10.87$, $P < 0.001$; Nest bowl to 5 meter, $q = 9.76$, $P < 0.001$
[d] For nests at the bowl, litter depth did not differ across years post-burn, both $q \leq 1.66$, $P \geq 0.995$
[e] At 1 m, one year post-burn to three year post-burn, $q = 5.67$, $P < 0.001$; at 5 m, one year post-burn to three year post-burn, $q = 5.66$, $P < 0.001$
[f] For all distances of patch and field plots, year 1 post-burn differed from both year 2and year 3 post-burn, all $q \geq 4.53$, $P < 0.01$.

Table 9. Interaction between year post-burn, plot type, and distance from nest bowl/center for residual hits at Savannah Sparrow nest, patch, and field plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences. All post hoc tests have 66 df.

Year post-burn, distance	Plot Type		
	Nest	Patch	Field
1, Nest bowl/center [a]	5.28 (0.58) A	1.61 (0.30) B	1.48 (0.52) B
1, 1meter	2.11 (0.59)	1.62 (0.31)	1.55 (0.45)
1, 5meter	2.20 (0.59)	1.61 (0.34)	1.67 (0.34)
2, Nest bowl/center	5.80 (0.32)	5.12 (0.53)	5.13 (1.10)
2, 1meter	5.27 (0.47)	5.08 (0.54)	4.88 (1.14)
2, 5 meter	5.17 (0.42)	4.93 (0.57)	4.88 (1.11)
3, Nest bowl	6.96 (0.93)	6.50 (1.02)	6.82 (1.11)
3, 1meter	7.26 (1.41)	6.48 (0.82)	6.55 (1.03)
3, 5meter	7.28 (0.68)	6.65 (0.70)	6.62 (0.81)
Year post-burn, Type	**Distance**		
	Nest bowl/center	1 meter	5 meter
1, Nest [b]	5.28 (0.58) A	2.11 (0.59) B	2.20 (0.59) B
Plot Type, Distance	**Year Post-burn [d]**		
	1	2	3
Nest, nest bowl [c]	5.28 (0.58)	5.80 (0.32)	6.96 (0.93)

[a] Nest to patch, $q = 9.50$, $P < 0.001$; nest to field, $q = 9.84$, $P < 0.001$

[b] Nest bowl to 1 meter, $q = 11.33$, $P < 0.001$; nest bowl to 5 m, $q = 11.01$, $P < 0.001$

[c] For nests at the bowl, dead hits did not differ across year post-burn, all $q \leq 3.36$, $P \geq 0.178$

[d] For nests at 1 m and 5 m, and all distances of patch and field plots, year 1 plots differed from both year 2 and year 3 post-burn plots, all $q \geq 5.43$, df = 66, $P < 0.001$

Table 10. Interaction between year post-burn, plot type, and distance from nest bowl/center for variation in residual hits at Savannah Sparrow nest, patch, and field plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences. All post hoc tests have 66 df.

Year post-burn, distance	Plot Type		
	Nest	Patch	Field
1, Nest bowl/center [a]	33.03 (3.62) A	87.63 (20.31) B	84.51 (11.84) B
1, 1meter	100.71 (24.63)	100.75 (13.11)	90.93 (17.69)
1, 5meter	93.00 (23.87)	102.72 (6.48)	85.65 (17.77)
2, Nest bowl/center	28.80 (1.64)	29.73 (3.02)	25.49 (1.36)
2, 1meter	31.71 (7.88)	35.89 (2.69)	33.33 (9.47)
2, 5 meter	33.90 (2.52)	39.74 (6.01)	34.75 (3.59)
3, Nest bowl [b]	28.63 (6.07) A	26.83 (3.20) A	19.95 (3.10) B
3, 1meter	26.61 (5.05)	31.92 (5.99)	25.18 (3.78)
3, 5meter	34.82 (7.98)	40.55 (6.10)	27.05 (2.51)
Year post-burn, Type	**Distance**		
	Nest bowl/center	1 meter	5 meter
1, Nest [c]	33.03 (3.62) A	100.71 (24.63) B	93.00 (23.87) B
Plot Type, Distance	**Year Post-burn [e]**		
	1	2	3
Nest, nest bowl [d]	33.03 (3.62)	28.80 (1.64)	28.63 (6.07)

[a] Nest to patch, $q = 5.27$, $P < 0.001$; nest to field, $q = 5.23$, $P < 0.001$

[b] Nest to patch, $q = 5.17$, $P < 0.001$; nest to field, $q = 4.65$, $P < 0.004$

[c] Nest bowl to 1 meter, $q = 6.00$, $P < 0.001$; nest bowl to 5 m, $q = 5.75$, $P < 0.001$

[d] For nests at the bowl, variation in dead hits did not differ across year post-burn, all $q \leq 1.64$, $P \geq 0.996$

[e] For nests at 1 m and 5 m, and all distances of patch and field plots, year 1 post-burn plots differed from both year 2 and year 3 post-burn plots, all $q \geq 4.22$, $P \leq 0.017$

Table 11. Interaction between year post-burn, plot type, and distance from nest bowl/center for percent grass hits at Savannah Sparrow nest, patch, and field plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences. All post hoc tests have 66 df.

Year post-burn, distance	Plot Type		
	Nest	Patch	Field
1, Nest bowl/center [a]	53.78 (5.30) A	75.94 (1.08) B	80.11 (5.77) B
1, 1meter	73.02 (3.59)	76.51 (1.21)	81.68 (6.19)
1, 5meter	72.40 (8.49)	75.36 (5.64)	78.43 (5.53)
2, Nest bowl/center	44.45 (2.90) A	51.98 (3.69) AB	56.00 (2.14) B
2, 1meter	47.75 (3.57)	52.58 (3.02)	56.89 (4.03)
2, 5 meter	49.49 (2.09)	52.25 (2.48)	58.40 (1.19)
3, Nest bowl [b]	40.04 (5.81) A	44.71 (7.53) A	52.28 (3.99) B
3, 1meter [c]	43.28 (7.82) A	42.90 (7.47) A	53.03 (3.72) B
3, 5meter [d]	44.07 (7.65) A	46.67 (6.59) AB	52.90 (4.07) B

Year post-burn, Type	Distance		
	Nest bowl/center	1 meter	5 meter
1, Nest [e]	53.78 (5.30) A	73.02 (3.59) B	72.40 (8.49) B

Plot Type, Distance	Year Post-burn [f]

[a] Nest to patch, $q = 5.10$, $P < 0.001$; nest to field, $q = 5.68$, $P < 0.001$

[b] Nest to field, $q = 6.91$, $P < 0.001$; patch to field, $q = 4.09$, $P = 0.026$

[c] Nest to field, $q = 5.40$, $P < 0.001$; patch to field, $q = 5.51$, $P < 0.001$

[d] Nest to field, $q = 4.80$, $P = 0.003$

[e] Nest bowl to 1 meter, $q = 7.43$, $P < 0.001$, nest bowl to 5 meter, $q = 7.08$, $P < 0.001$

[f] For all plot type and distance combinations, year 1 post-burn differed from year 3 post-burn, all $q \geq 4.21$, $P \leq 0.018$.

Table 12. Interaction between year post-burn and plot type for litter depth (cm) at Blue-winged Teal nest, patch, and field plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences ($q = 5.27$, df $= 12$, $P \leq 0.05$)

Plot Type	Year Post-burn		
	Year 1	Year 2	Year 3
Nest	0.58 (0.16) A	1.91 (0.62) B	2.71 (1.70) B
Patch	0.65 (0.21) A	1.28 (0.63) A	3.13 (1.86) B
Field	0.38 (0.16) A	2.28 (1.18) B	3.90 (1.13) B

Year Post-burn	Plot Type		
	Nest	Patch	Field
Year 1	0.58 (0.16)	0.65 (0.21)	0.38 (0.16)
Year 2	1.91 (0.62)	1.28 (0.63)	2.28 (1.18)
Year 3	2.71 (1.70)	3.13 (1.86)	3.90 (1.13)

Table 13. Interaction between year post-burn and plot type for residual hits at Blue-winged Teal nest, patch, and field plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences ($q = 5.27$, df = 12, $P \leq 0.05$).

Plot Type	Year Post-burn		
	Year 1	Year 2	Year 3
Nest	3.00 (0.25) A	4.85 (1.02) B	6.29 (1.54) C
Patch	2.76 (0.23) A	4.30 (0.84) B	6.74 (1.65) C
Field	1.57 (0.41) A	4.96 (1.02) B	6.66 (0.94) C

Year Post-burn	Plot Type		
	Nest	Patch	Field
Year 1	3.00 (0.25) A	2.76 (0.23) A	1.57 (0.41) B
Year 2	4.85 (1.02) A	4.30 (0.84) B	4.96 (1.02) A
Year 3	6.29 (1.54)	6.74 (1.65)	6.66 (0.94)

Table 14. Interaction between plot type and distance from nest bowl/plot center for percent grass hits at Blue-winged Teal nest, patch, and field plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences ($q = 4.60$, df = 46, $P \leq 0.05$).

Distance	Plot Type		
	Nest	Patch	Field
Nest bowl/center	53.34 (9.90) A	48.50 (10.31) A	61.30 (13.03) B
1 meter	49.11 (12.13) A	49.53 (9.81) A	62.32 (13.50) B
5 meter	47.39 (11.01) A	48.50 (10.85) A	61.76 (11.79) B

Plot Type	Distance		
	Nest bowl/center	1 meter	5 meter
Nest	53.34 (9.90) A	49.11 (12.13) AB	47.39 (11.01) B
Patch	48.50 (10.31)	49.53 (9.81)	48.50 (10.85)
Field	61.30 (13.03)	62.32 (13.50)	61.76 (11.79)

Table 15. Interaction between year post-burn and plot type for distance to shrub (m) at Blue-winged Teal nest, patch, and field plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences ($q = 5.27$, df $= 12$, $P \leq 0.05$)

Plot Type	Year Post-burn		
	Year 1	Year 2	Year 3
Nest	13.80 (0.79)	26.25 (17.69)	26.49 (7.99)
Patch	16.11 (4.69)	27.91 (17.26)	23.33 (9.87)
Field	29.39 (3.74)	26.72 (4.11)	24.85 (3.93)

Year Post-burn	Plot Type		
	Nest	Patch	Field
Year 1	13.80 (0.79)	16.11 (4.69)	29.39 (3.74)
Year 2	26.25 (17.69)	27.91 (17.26)	26.72 (4.11)
Year 3	26.49 (7.99)	23.33 (9.87)	24.85 (3.93)

Table 16. Interaction between year post-burn and plot type for vegetation heterogeneity at Blue-winged Teal nest, patch, and field plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences ($q = 5.27$, df = 12, $P \leq 0.05$)

Plot Type	Year Post-burn		
	Year 1	Year 2	Year 3
Nest	23.05 (1.21) A	20.48 (7.63) A	13.74 (5.26) B
Patch	21.70 (3.25) A	15.98 (10.76) B	14.01 (6.48) B
Field	10.73 (1.37)	10.97 (0.66)	10.52 (2.62)
Year Post-burn	Plot Type		
	Nest	Patch	Field
Year 1	23.05 (1.21) A	21.70 (3.25) A	10.73 (1.37) B
Year 2	20.48 (7.63) A	15.98 (10.76) B	10.97 (0.66) C
Year 3	13.74 (5.26) A	14.01 (6.48) A	10.52 (2.62) B

APPENDIX B

POST-HOC TEST RESULTS FOR CHAPTER 3

Table 1. Interaction between type and distance for height density at successful and failed Clay-colored Sparrow nest and patch plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences ($q = 4.77$, df = 76, $P \leq 0.05$)

Distance	Plot Type			
	Failed Nest	Failed Patch	Successful Nest	Successful Patch
Nest bowl	4.87 (0.79) A	3.91 (1.17) B	4.83 (0.53) A	3.45 (0.59) C
1m	4.68 (0.78) A	4.08 (1.15) B	4.79 (0.60) A	3.63 (0.43) C
5m	4.55 (0.74) A	4.14 (1.05) BC	4.28 (0.53) AB	3.80 (0.58) C

Plot Type	Distance from nest bowl / plot center		
	Nest bowl	1m	5m
Failed Nest	4.87 (0.79) A	4.68 (0.78) A	4.55 (0.74) A
Failed Patch	3.91 (1.17) A	4.08 (1.15) A	4.14 (1.05) A
Successful Nest	4.83 (0.53) A	4.79 (0.60) A	4.28 (0.53) B
Successful Patch	3.45 (0.59) A	3.63 (0.43) AB	3.80 (0.58) B

Table 2. Interaction between group, type, and distance for percent grass hits measured at successful and failed Clay-colored Sparrow nest and patch plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences. All post- hoc tests have 76 df.

	Failed Nest	Failed Patch	Successful Nest	Successful Patch
1, Nest bowl [a]	47.28 (12.44) A	73.26 (6.78) B	28.05 (7.96) A	71.23 (4.39) B
1, 1m [b]	57.93 (20.77) A	76.17 (8.48) B	51.09 (13.51) A	77.78 (6.29) B
1, 5m	68.65 (9.12)	71.29 (3.48)	65.31 (7.06)	77.02 (6.08)
2, Nest bowl [c]	34.27 (4.34) AB	47.92 (3.16) A	32.54 (6.87) B	47.31 (7.02) A
2, 1m	50.12 (8.59)	46.98 (1.33)	41.94 (6.19)	49.87 (4.58)
2, 5 m	47.45 (7.93)	47.64 (3.02)	51.06 (8.28)	49.98 (5.77)
3, Nest bowl [d]	34.57 (4.67) A	47.63 (8.83) B	38.38 (5.12) AB	43.21 (5.43) AB
3, 1m	50.06 (8.40)	45.90 (4.41)	45.08 (4.45)	48.12 (3.21)
3, 5m	46.28 (4.18)	48.01 (2.31)	47.78 (3.16)	48.61 (2.37)

[a] Failed nest to failed patch, $q = 6.84$, $P < 0.001$; successful nest to successful patch, $q = 11.72$, $P < 0.001$.

[b] Failed nest to failed patch, $q = 4.84$, $P = 0.003$; successful nest to successful patch, $q = 7.21$, $P < 0.001$.

[c] Successful nest to successful patch, $q = 4.33$, $P = 0.018$.

[d] Failed nest to failed patch, $q = 4.69$, $P = 0.005$.

Table 3. Interaction between group, type, and distance for residual hits measured at successful and failed Clay-colored Sparrow nest and patch plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences. All post- hoc tests have 76 df.

Year post-burn, distance	Plot type			
	Failed Nest	Failed Patch	Successful Nest	Successful Patch
1, Nest bowl [a]	4.13 (1.02) AB	1.94 (1.08) B	5.60 (0.52) A	1.77 (0.65) B
1, 1m	3.97 (1.06)	2.39 (0.84)	3.91 (0.96)	1.56 (0.74)
1, 5m	2.07 (1.24)	2.47 (0.56)	3.26 (0.30)	1.88 (0.50)
2, Nest bowl	6.43 (0.32)	5.00 (0.59)	6.40 (0.75)	5.56 (0.03)
2, 1m	5.50 (0.65)	5.08 (0.59)	6.02 (1.21)	5.09 (0.33)
2, 5 m	5.83 (0.17)	4.97 (0.53)	6.44 (0.64)	5.22 (0.28)
3, Nest bowl	7.49 (1.23)	7.01 (1.59)	7.09 (0.79)	7.81 (1.66)
3, 1m	6.70 (1.01)	7.32 (1.01)	7.17 (1.59)	7.45 (1.07)
3, 5m	6.94 (1.15)	6.82 (0.92)	7.80 (1.13)	7.18 (0.96)

Plot type, distance	Year post-burn		
	1	2	3
Failed Nest, Nest bowl [b]	4.13 (1.02) A	6.43 (0.32) AB	7.49 (1.23) B
Failed Patch, Nest bowl [c]	1.94 (1.08) A	5.00 (0.59) AB	7.01 (1.59) B
Successful Nest, Nest bowl [d]	5.60 (0.52)	6.40 (0.75)	7.09 (0.79)
Successful Patch, Nest bowl [e]	1.77 (0.65) A	5.56 (0.03) B	7.81 (1.66) B

[a] Successful nest to successful patch, $q = 4.95$, $P = 0.002$; successful nest to failed patch, $q = 4.54$, $P = 0.009$.

[b] One year to three year, $q = 4.74$, $P = 0.005$.

[c] One year to three year, $q = 7.15$, $P < 0.001$.

[d] Did not differ across year post-burn, $q \leq 2.23$, $P \geq 0.945$.

[e] One year to two year, $q = 5.07$, $P = 0.001$; one year to three year, $q = 8.65$, $P < 0.001$.

Table 4. Interaction between group and type for vegetation density at successful and failed Clay-colored Sparrow nest and patch plots at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences ($q = 5.04$, df = 27, $P \leq 0.05$).

Year post-burn	Plot Type			
	Failed Nest	Failed Patch	Successful Nest	Successful Patch
1	272.00 (61.58) A	198.86 (66.17) B	216.73 (28.77) AB	164.16 (29.74) B
2	252.66 (13.00) AB	199.18 (21.26) B	281.42 (19.97) A	218.59 (17.14) B
3	286.71 (27.82) AB	237.65 (32.28) B	290.13 (36.43) A	254.99 (28.49) AB

Plot Type	Year post-burn		
	1	2	3
Failed Nest	272.00 (61.58)	252.66 (13.00)	286.71 (27.82)
Failed Patch	198.86 (66.17)	199.18 (21.26)	237.65 (32.28)
Successful Nest	164.16 (29.74) A	281.42 (19.97) AB	290.13 (36.43) B
Successful Patch	216.73 (28.77) A	218.59 (17.14) AB	254.99 (28.49) B

Table 5. Interaction between group, type, and distance for height density measures at successful and failed Blue-winged Teal nest and patch plots measured at J. Clark Salyer NWR 1999-2000. Within rows, columns with different letters indicate significant differences. All post- hoc tests have 40 df.

Year post-burn, distance	Plot Type			
	Failed Nest	Failed Patch	Successful Nest	Successful Patch
1, Nest bowl	4.81 (0.0)	4.61 (2.00)	3.58 (0.66)	3.45 (2.29)
1, 1m	4.67 (0.42)	4.74 (2.11)	3.43 (0.80)	3.48 (2.33)
1, 5m	5.45 (1.08)	4.66 (1.56)	3.44 (2.03)	3.35 (1.92)
2, Nest bowl	3.11 (0.66)	3.54 (0.33)	3.24 (0.55)	3.60 (0.59)
2, 1m	2.91 (0.32)	3.52 (0.42)	3.08 (0.33)	3.50 (0.93)
2, 5 m	3.59 (0.26)	3.65 (0.55)	3.35 (0.74)	3.48 (0.89)
3, Nest bowl [a]	2.70 (0.26) AB	2.77 (0.52) AB	1.60 (0.22) A	3.49 (0.02) B
3, 1m [b]	2.45 (0.46) AB	2.90 (0.57) A	1.31 (0.44) B	3.56 (0.09) A
3, 5m	2.83 (0.62)	3.10 (0.76)	3.19 (0.27)	3.16 (0.37)
Year post-burn, plot type	Distance			
	Nest bowl/center	1 meter	5 meter	
3, Failed Nest [c]	2.70 (0.26)	2.45 (0.46)	2.83 (0.62)	
3, Failed Patch [c]	2.77 (0.52)	2.90 (0.57)	3.10 (0.76)	
3, Successful Nest [d]	1.60 (0.22) A	1.31 (0.44) A	3.19 (0.27) B	
3, Successful Patch [c]	3.49 (0.02)	3.56 (0.09)	3.16 (0.37)	

[a] Successful nest to successful patch, $q = 4.64$, $P = 0.013$.

[b] Successful nest to successful patch, $q = 6.04$, $P < 0.001$, successful nest to failed patch, $q = 5.08$, $P = 0.004$.

[c] None differed by distance, all q's ≤ 1.59, P's ≥ 0.99.

[d] Nest bowl to 5 m, $q = 5.66$, $P = 0.001$; 1 m to 5 m, $q = 7.44$, $P < 0.001$. ....

APPENDIX C

SUMMARY OF NESTS, PATCH PLOTS, AND FIELD PLOTS MEASURED AT J. CLARK SALYER NATIONAL WILDLIFE REFUGE, 1998-2000.

Table 1. Summary of Clay-colored Sparrow nests, patch plots, and field plots measured at J. Clark Salyer NWR, 1999-2000.

Unit	Year	Year post-burn	Nests			Patch			Field
			Success	Fail	Total[a]	Success	Fail	Total[a]	
A	1999	>3	4	1	6	12	3	18	14
A	2000	1	10	8	18	30	24	54	15
C	1999	2	3	5	8	9	15	24	15
C	2000	3	4	2	6	12	6	18	15
D	1999	>3	2	3	5	6	9	15	15
D	2000	1	1	1	2	3	3	6	15
F	1999	1	3	0	3	9	0	9	15
F	2000	2	7	8	15	21	24	45	15
G	1999	1	0	1	2	0	3	6	15
G	2000	2	1	0	1	3	0	3	15
H	1999	2	5	3	8	15	9	24	15
H	2000	3	1	4	5	3	12	15	15
I	1999	3	2	2	5	6	6	15	15
I	2000	>3	3	2	5	9	6	15	15
Totals			46	40	89	138	120	267	209

[a] Includes nests for which fate was unknown.

Table 2. Summary of Savannah Sparrow nests, patch plots, and field plots measured at J. Clark Salyer NWR, 1998-2000.

Unit	Year	Year post-burn	Nests			Patch			Field[a]
			Success	Fail	Total	Success	Fail	Total	
A	1998	>3	4	6	10	12	18	30	
A	1999	>3	2	4	6	6	12	18	14
A	2000	1	2	5	7	6	15	21	15
C	1998	1	0	0	0	0	0	0	
C	1999	2	4	2	6	12	6	18	15
C	2000	3	2	4	6	6	12	18	15
D	1998	>3	0	6	6	0	18	18	
D	1999	>3	4	3	7	12	9	21	15
D	2000	1	3	8	11	9	24	33	15
F	1998	>3	3	3	6	9	9	18	
F	1999	1	4	5	9	12	15	27	15
F	2000	2	3	6	9	9	18	27	15
G	1998	>3	3	2	5	9	6	15	
G	1999	1	1	2	3	3	6	9	15
G	2000	2	7	0	7	21	0	21	15
H	1998	1	0	1	1	0	3	3	
H	1999	2	4	6	10	12	18	30	15
H	2000	3	2	3	5	6	9	15	15
I	1998	2	1	1	2	3	3	6	
I	1999	3	5	0	5	15	0	15	15
I	2000	>3	4	1	5	12	3	15	15
Totals			58	68	126	174	204	378	209

[a] No field plots were measured in 1998; 1998 nests and patches used only in Ch. 3 analysis.

Table 3. Summary of Blue-winged Teal nests, patch plots, and field plots measured at J. Clark Salyer NWR, 1999-2000.

Unit	Year	Year post-burn	Nests[a]			Patch			Field
			Success	Fail	Total	Success	Fail	Total	
A	1999	>3	0	1	1	0	3	3	14
A	2000	1	1	4	5	3	12	15	15
C	1999	2	1	1	2	3	3	6	15
C	2000	3	2	5	7	6	15	21	15
D	1999	>3	0	0	0	0	0	0	15
D	2000	1	7	4	11	21	12	33	15
F	1999	1	0	0	0	0	0	0	15
F	2000	2	3	6	9	9	18	27	15
G	1999	1	0	0	0	0	0	0	15
G	2000	2	8	1	9	24	3	27	15
H	1999	2	0	0	0	0	0	0	15
H	2000	3	0	5	5	0	15	15	15
I	1999	3	0	0	0	0	0	0	15
I	2000	>3	1	6	7	3	18	21	15
Totals			23	33	56	69	99	168	209

[a] Due to limited personnel, only three nests were measured in 1999.